Basic Exploration Geophysics

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Good things come to those who work their hands off

Agenda

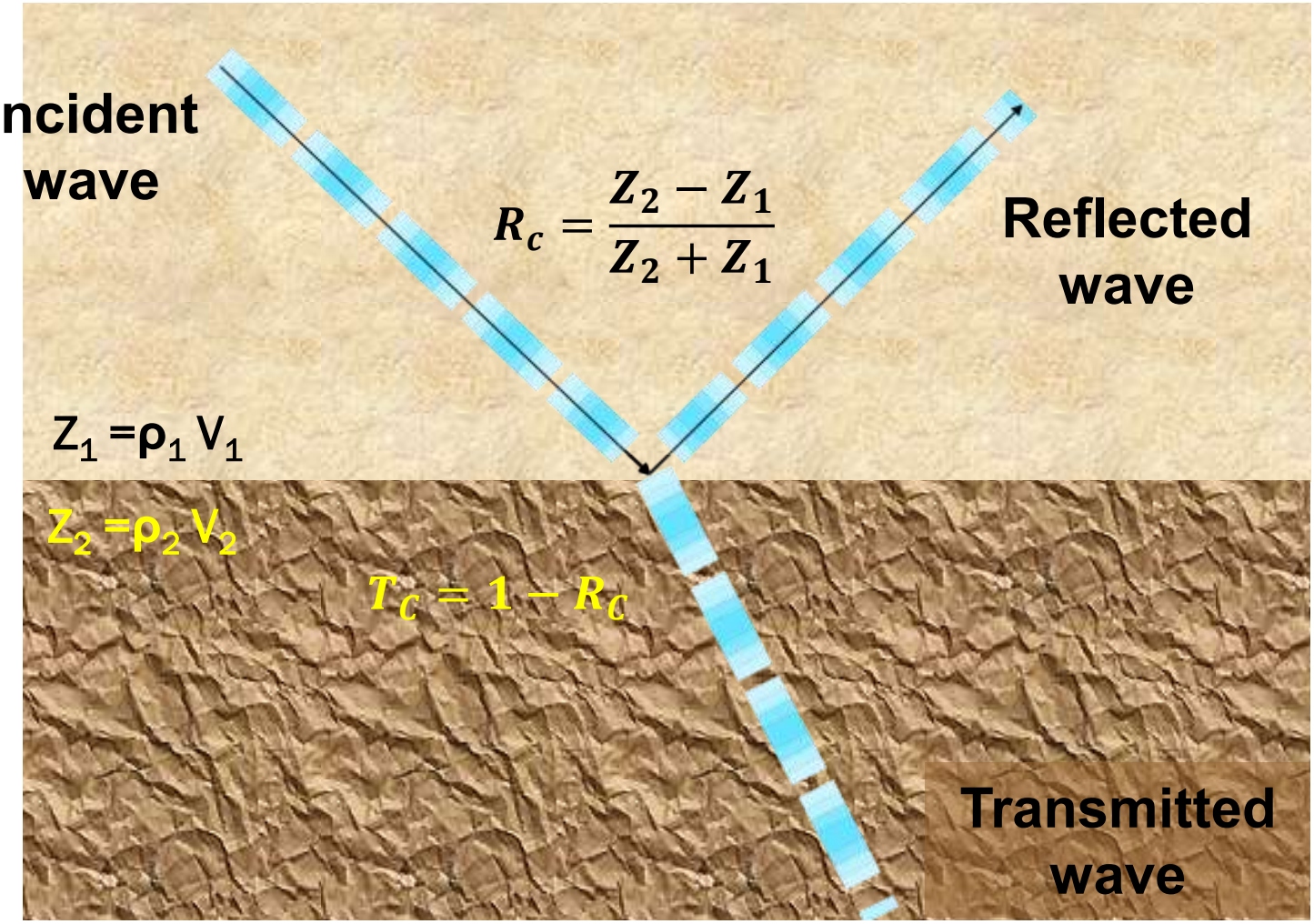
- Introduction to seismic reflection.
- Seismic interpretation & Subsurface Mapping.

Introduction To Seismic Reflection

Introduction To Seismic Reflection

- Seismic waves are the sound waves penetrating the earth.
- Seismic methods and subsurface mapping are key skills that are used commonly in the oil industry.
- Due to the heterogeneity of earth's layers; seismic waves changes its path when it encounter a bed boundary.
- The physical property in seismic reflection is the acoustic impedance $Z=\rho V$ where ρ is the density of the layer and V is the seismic velocity within it.
- Seismic boundary is defined as the surface where the acoustic impedance changes.

Introduction To Seismic Reflection

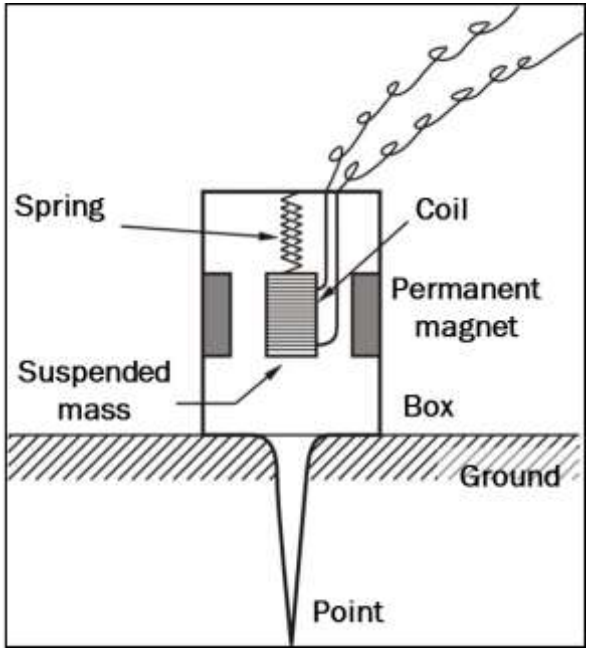


Seismic Sources

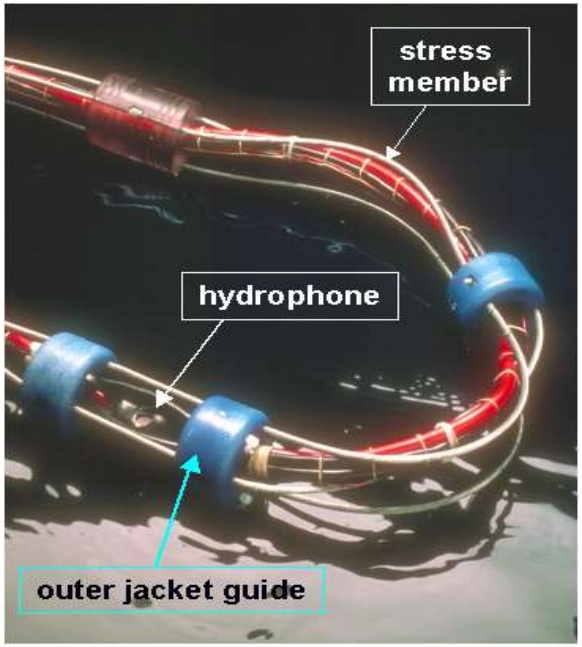
- Seismic source is the source where the seismic energy generated.
- The parameters of each source should be adjusted to favor the purpose of the survey (Frequency , amount of energy generated , recording length , …. Etc).
- For land purpose Vibrator or Dynamite is appropriate because the high depth of penetration and wide frequency range.
- For Marine We use Air Guns.

Seismic Receivers (Seismograph)

- The seismic energy generated by the different sources need to be received by a device which able to translate the seismic energy into electrical signal so it can be send to the recorder.



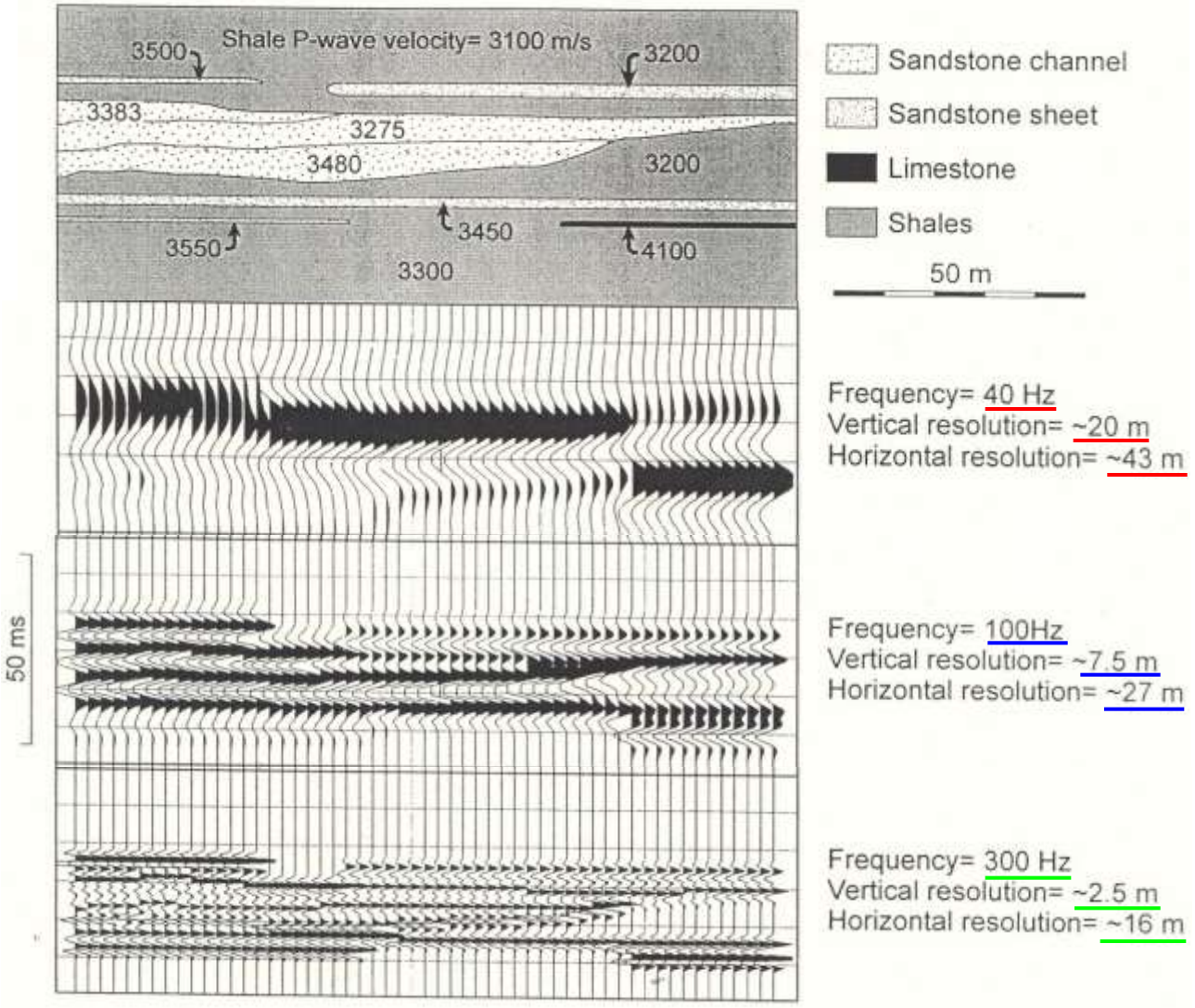
Geophone (land Receiver)



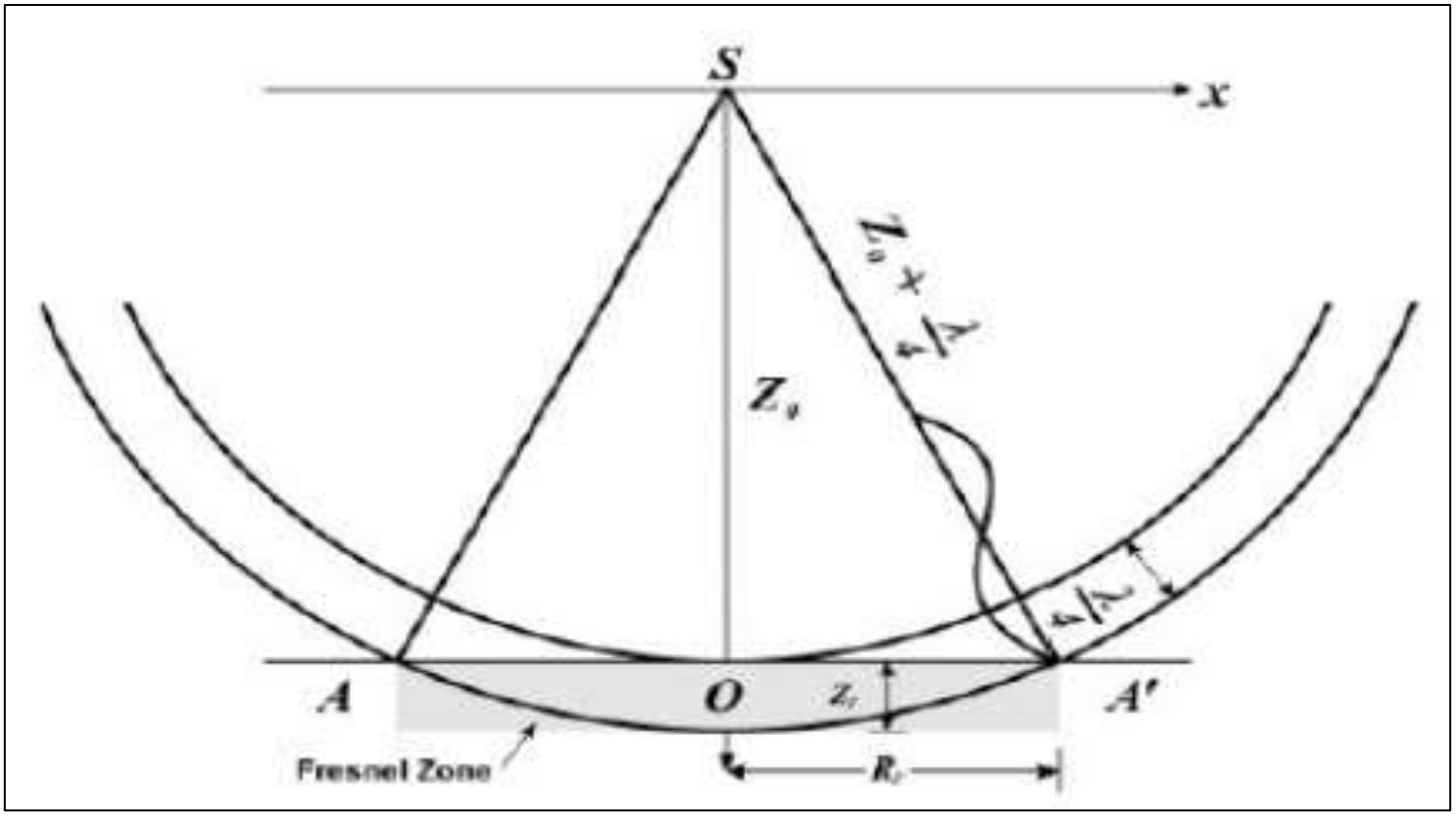
Hydrophone (Marine Receiver)

Frequency Content And Vertical/Horizontal Resolution

Vertical Resolution



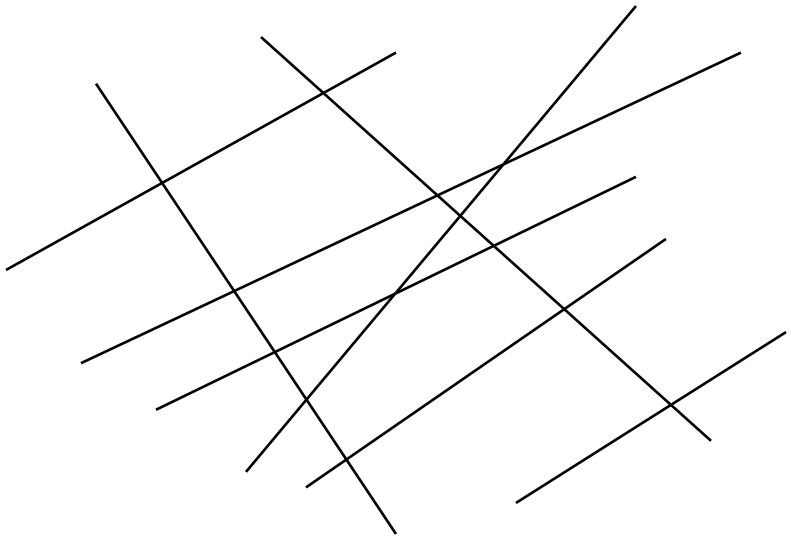
Frequency Content And Vertical/Horizontal Resolution

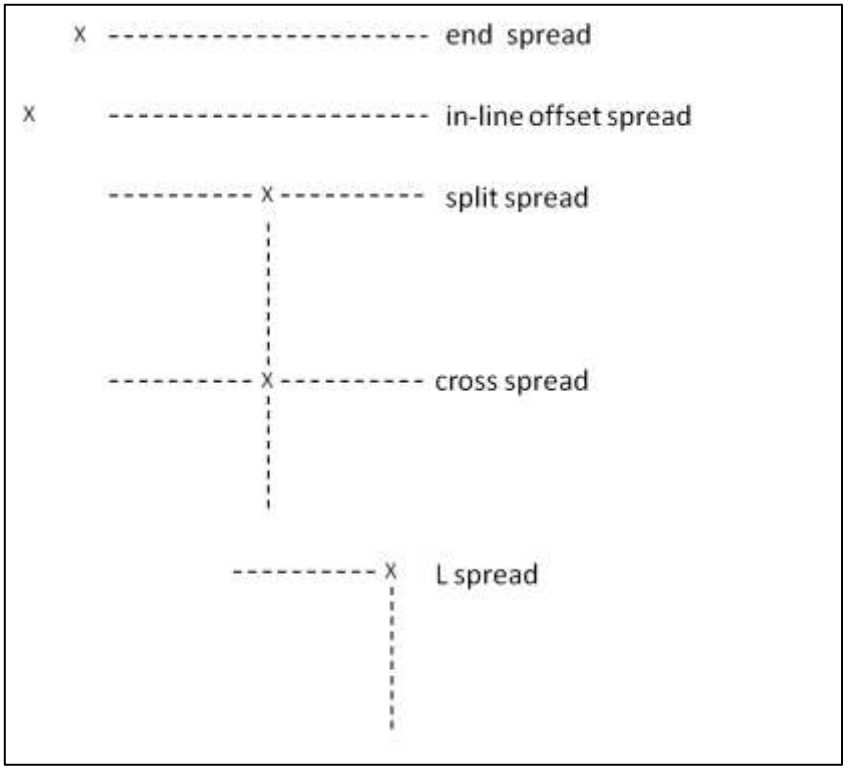


$$\text{Fresnel zone} = \frac{\text{V}}{4F}$$

Basic Spreads

A 2D survey consists of a grid of coarsely spaced seismic lines





3D surveys

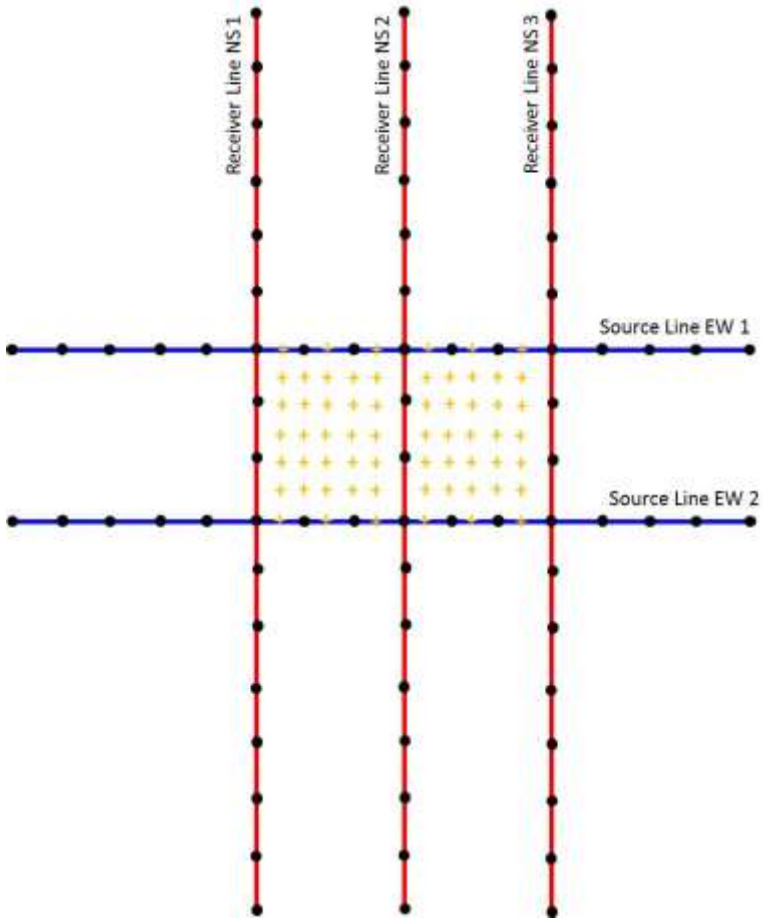
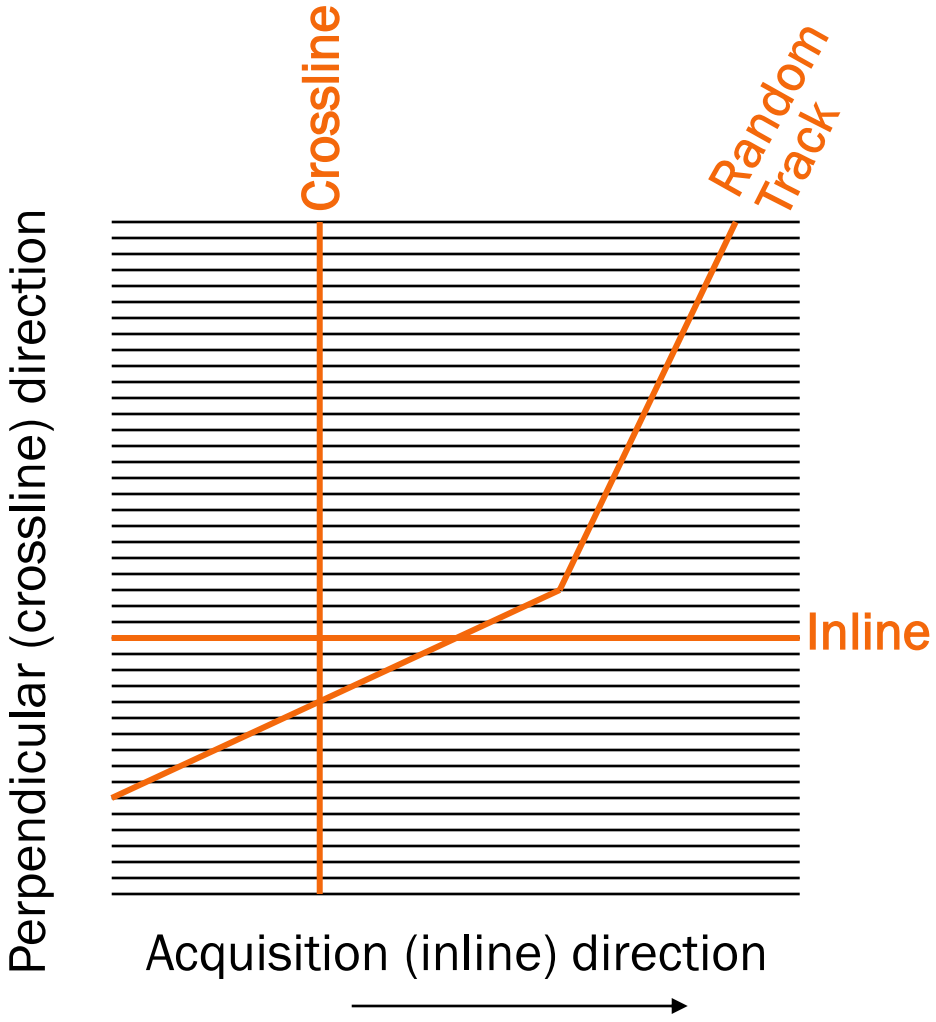
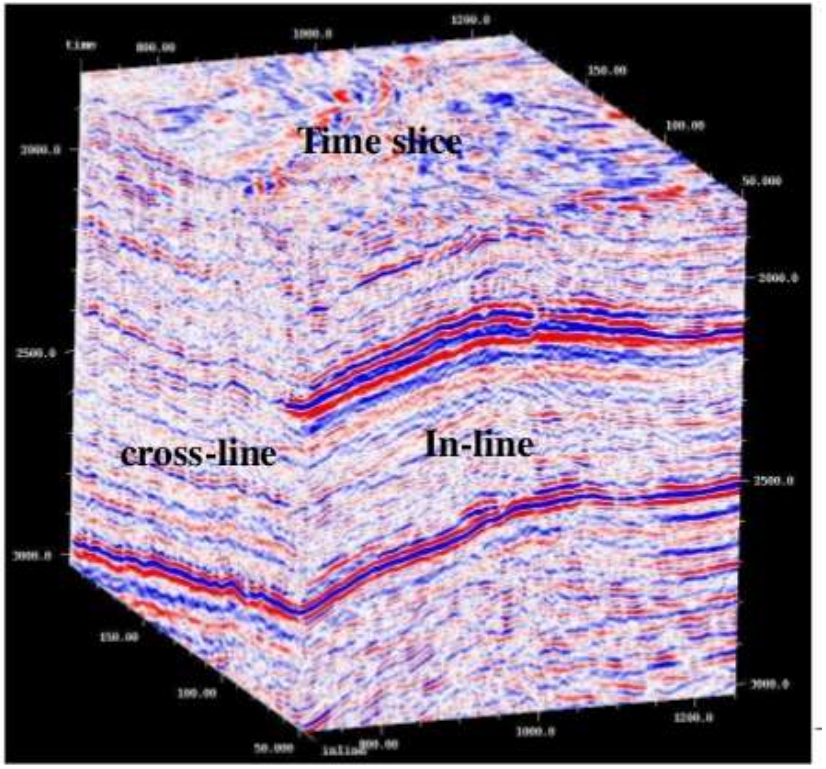


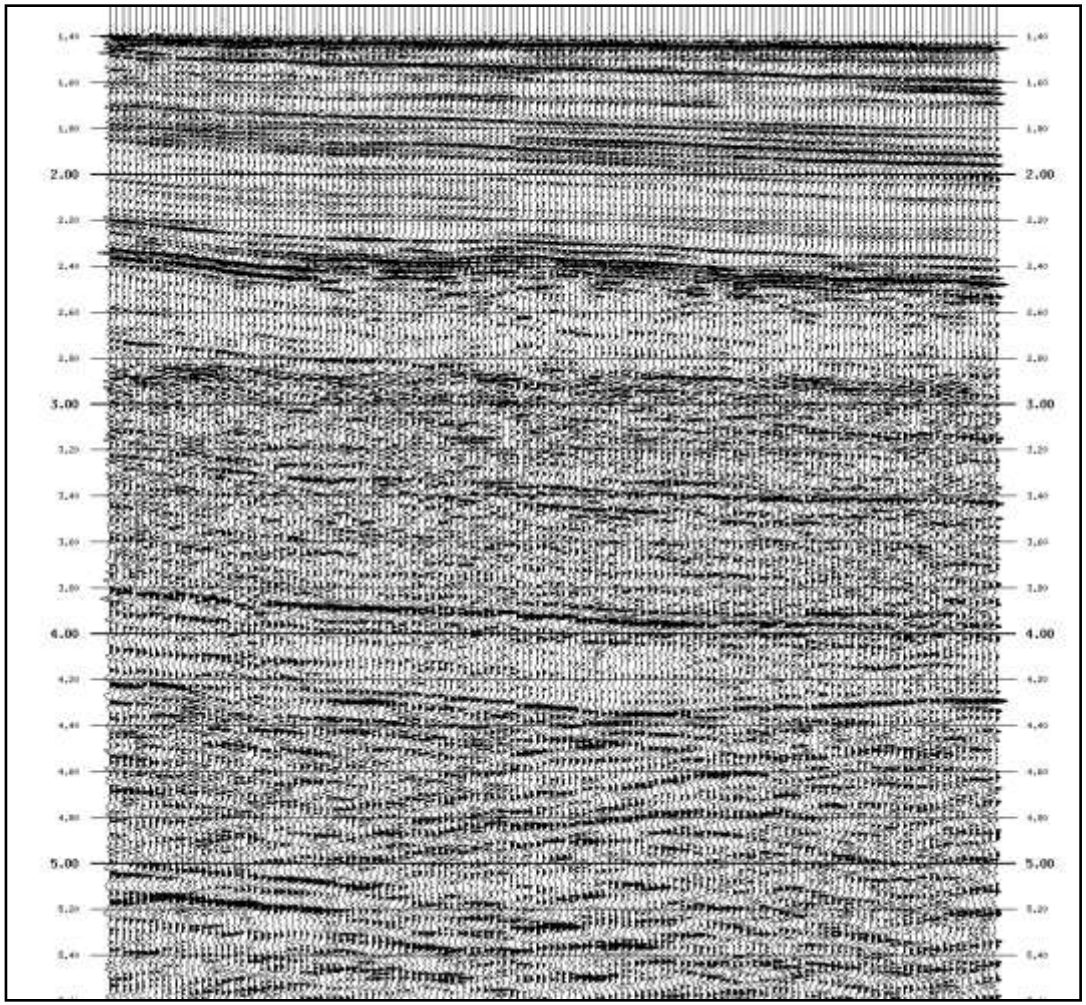
Figure 2-11 Diagram showing source and receiver locations (•)in the common midpoints (+) for a 3D seismic reflection survey.

3D surveys

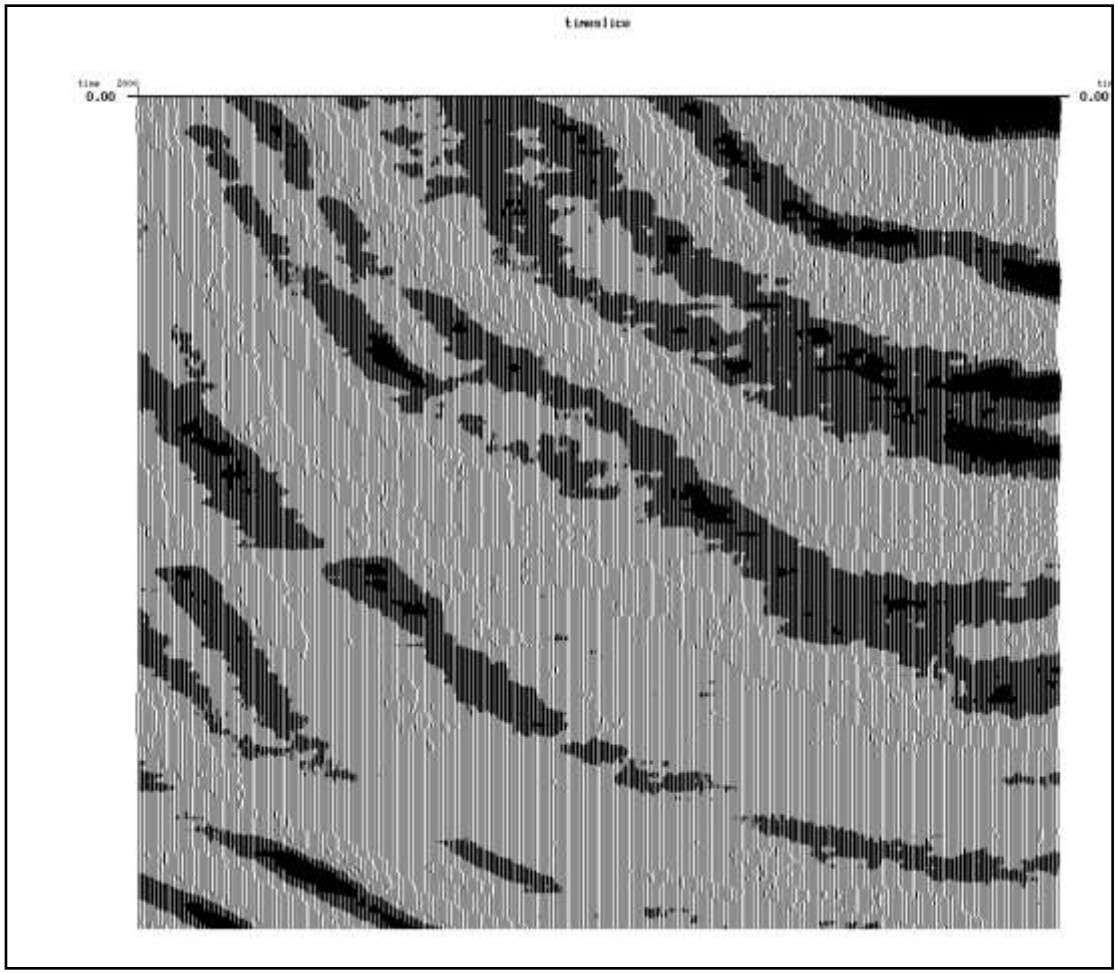

Crossline
Random Track
Inline
Perpendicular (crossline) direction
Acquisition (inline) direction


Time slice
cross-line
In-line

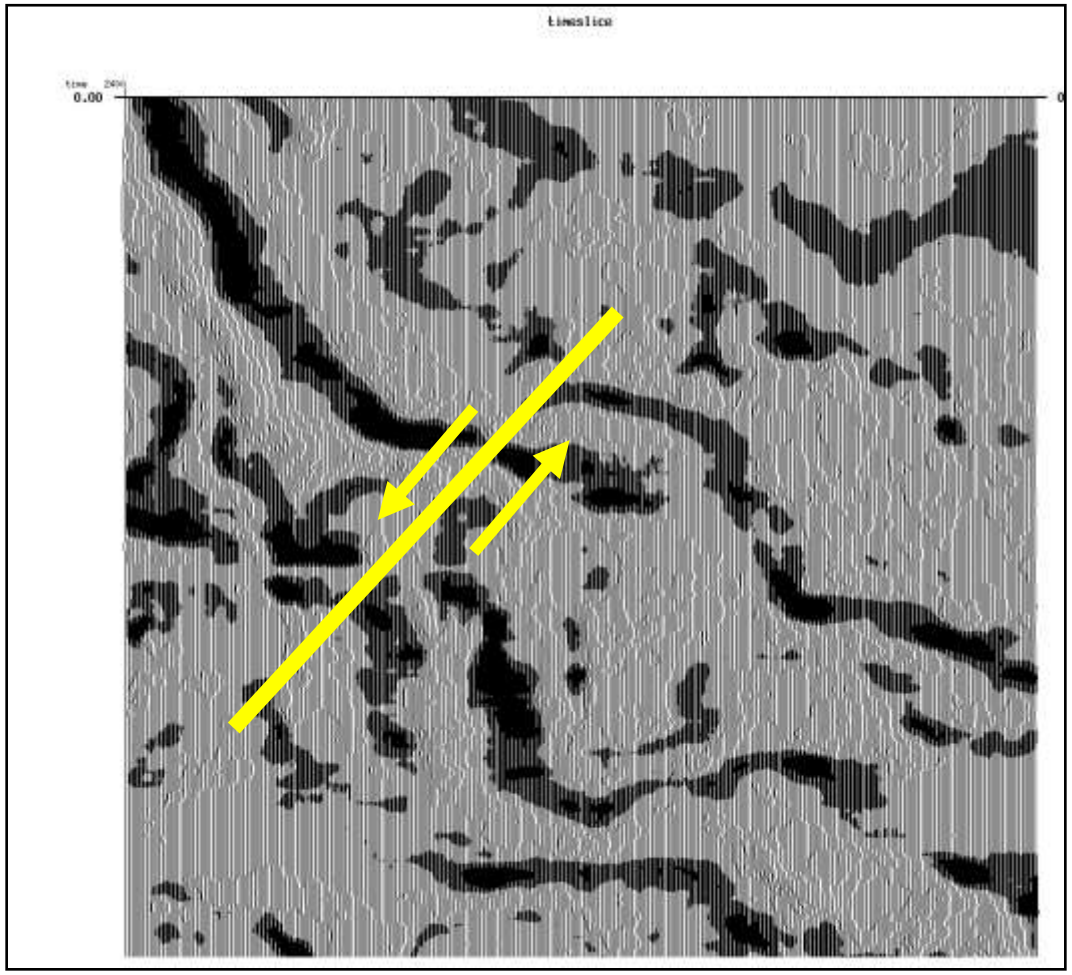
Crossline Section



Timeslice section at 2000msec

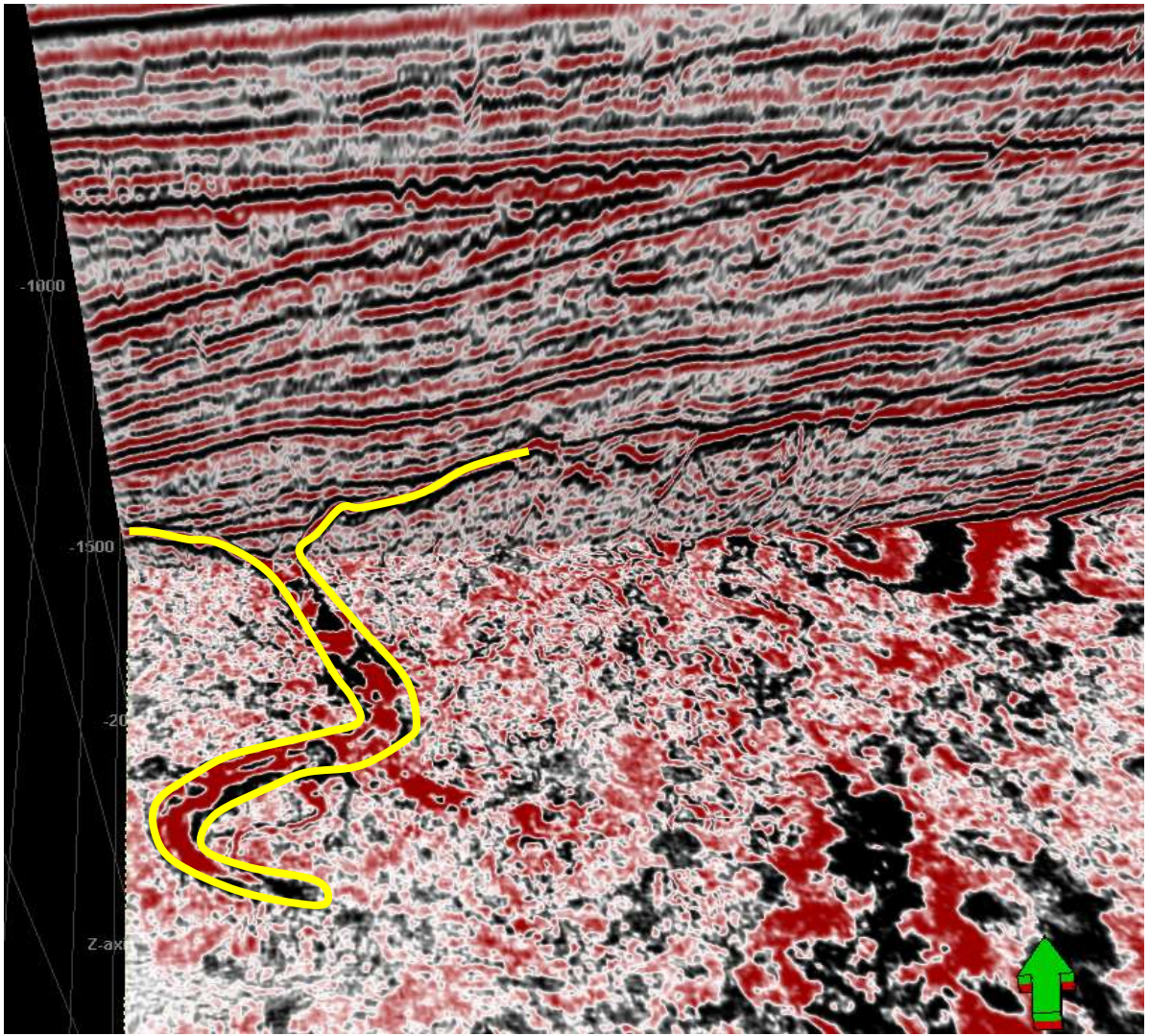


Timeslice at 2400msec

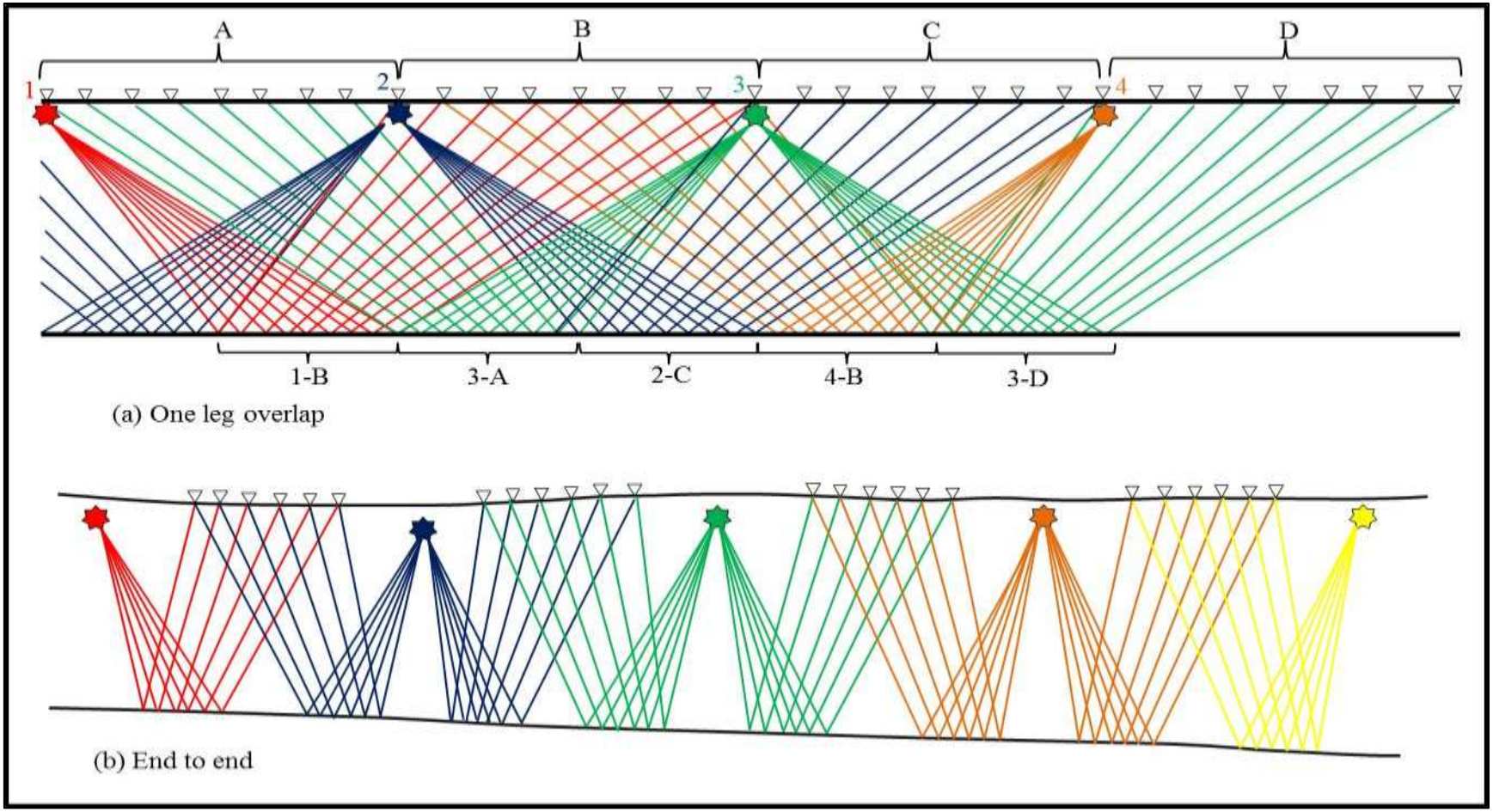


Strike Slip Fault

Detecting Channels on time slice

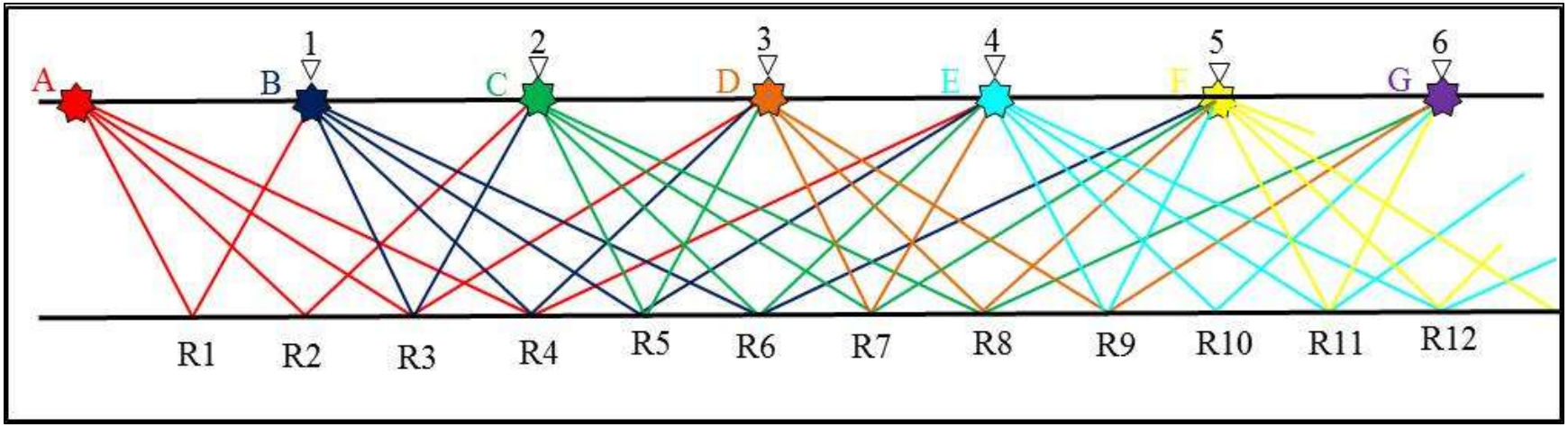


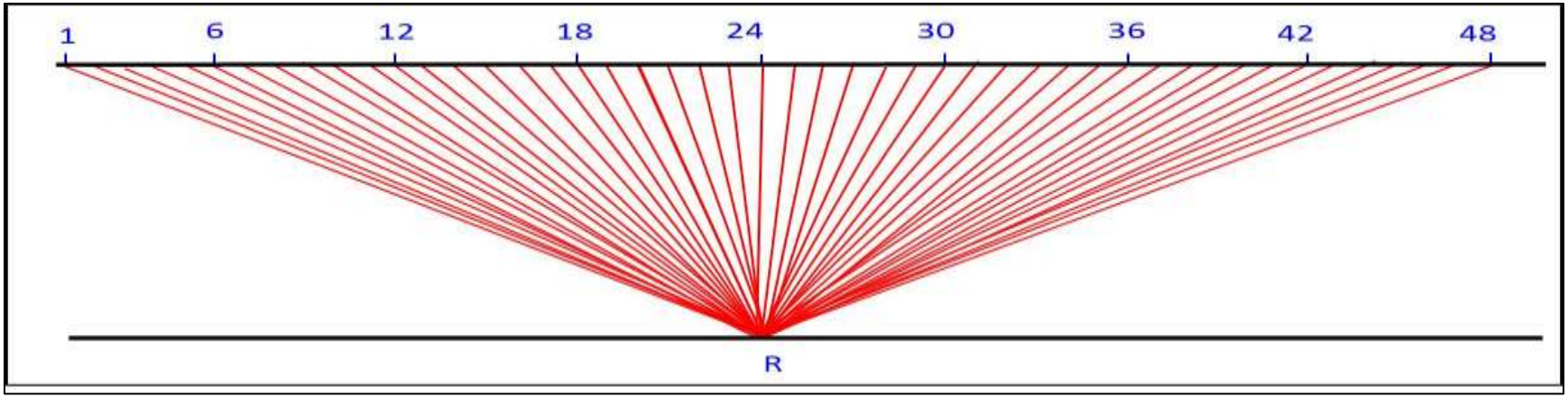
Single Coverage



Each CDP has covered one time.

Multiple Coverage



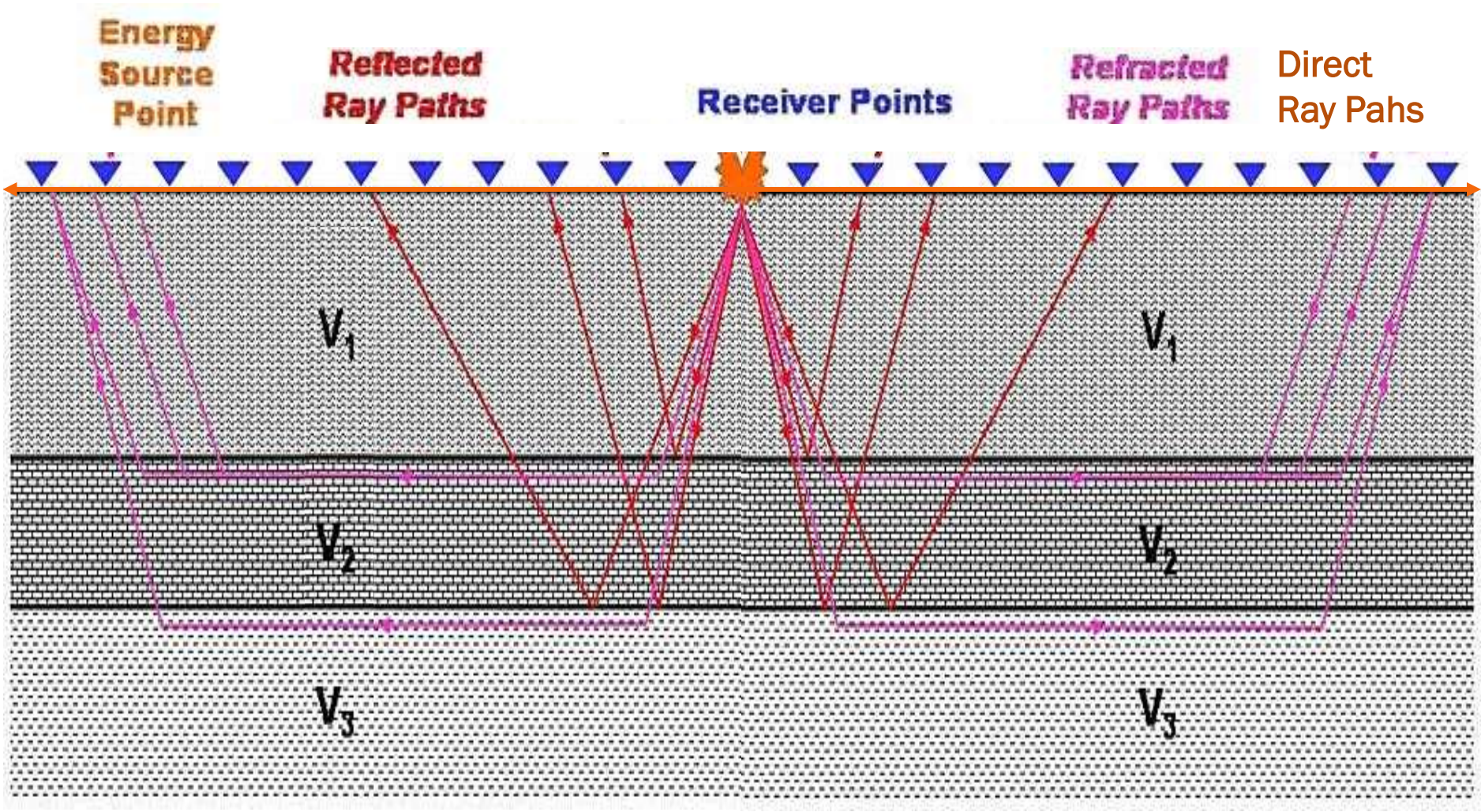


$$fold\ number = \frac{N}{2}\frac{\Delta x}{\Delta s}$$

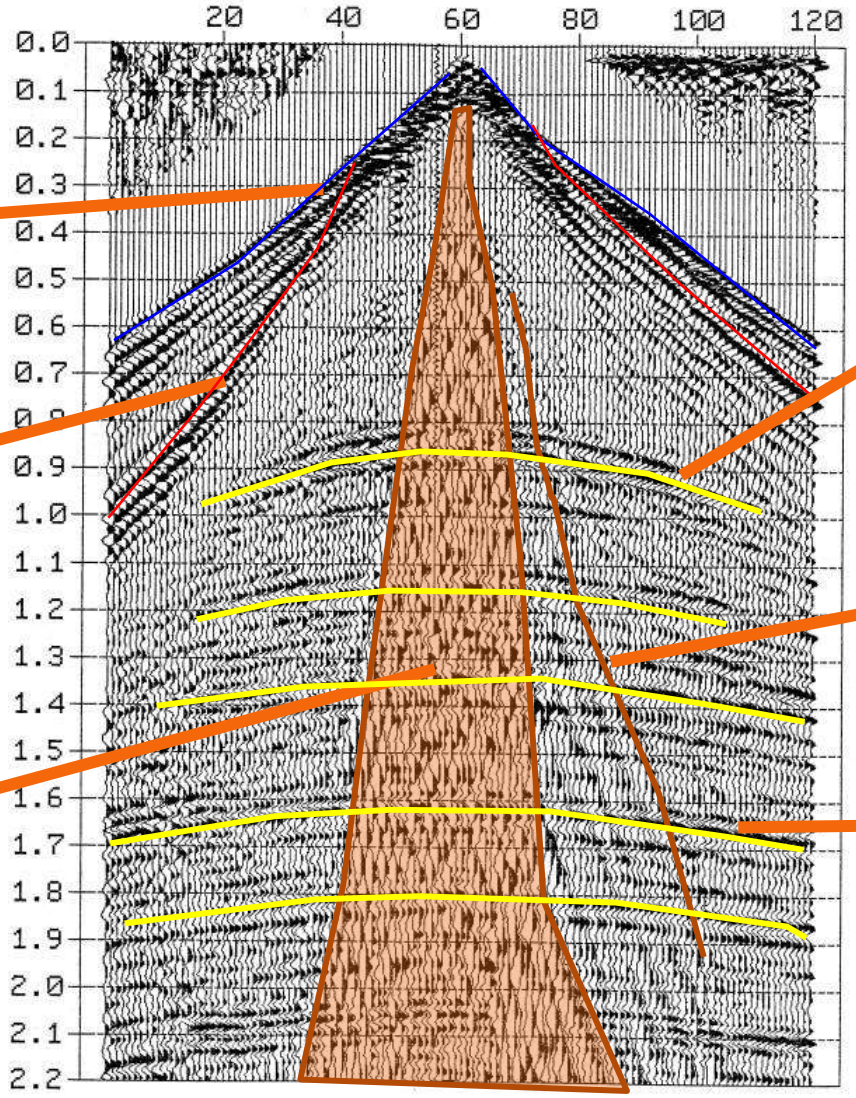
Seismogram (Recorder)

- The electrical signal generated by the seismograph is displayed on a profile where the X-axis represents the distance and the Y-axis represents the arrival Time.
- Raw records are in the form of the common shot gather.
- Each geophone is represented on the seismogram by one trace.
- In the first stages of processing we use the shot gathers to remove the effect of the ground roll & the linear events (direct & refracted waves).

Shot gathering



Shot gathering



Linear Event
(Direct Waves)

Linear Event
(Refracted Waves)

Ground Roll

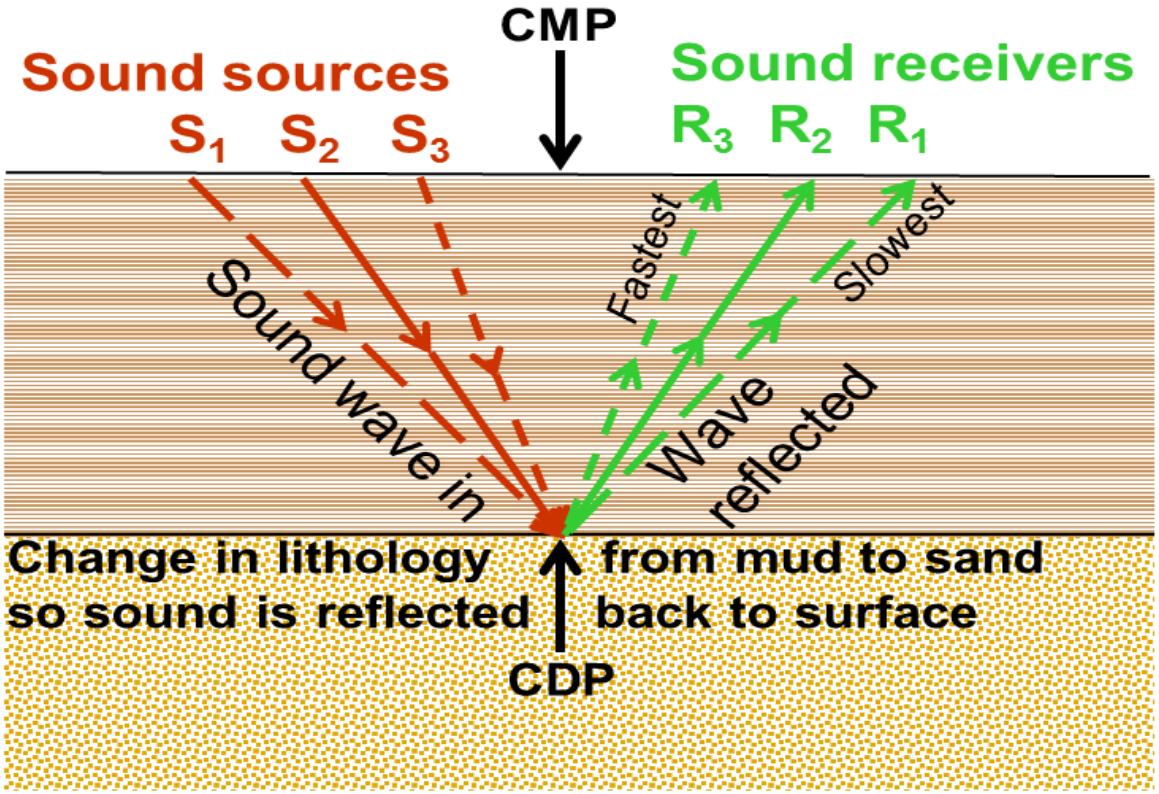
Curved Event
(Reflected Waves)

Later Linear Event
(Refracted Waves)

Later Curved Event
(Reflected Waves)

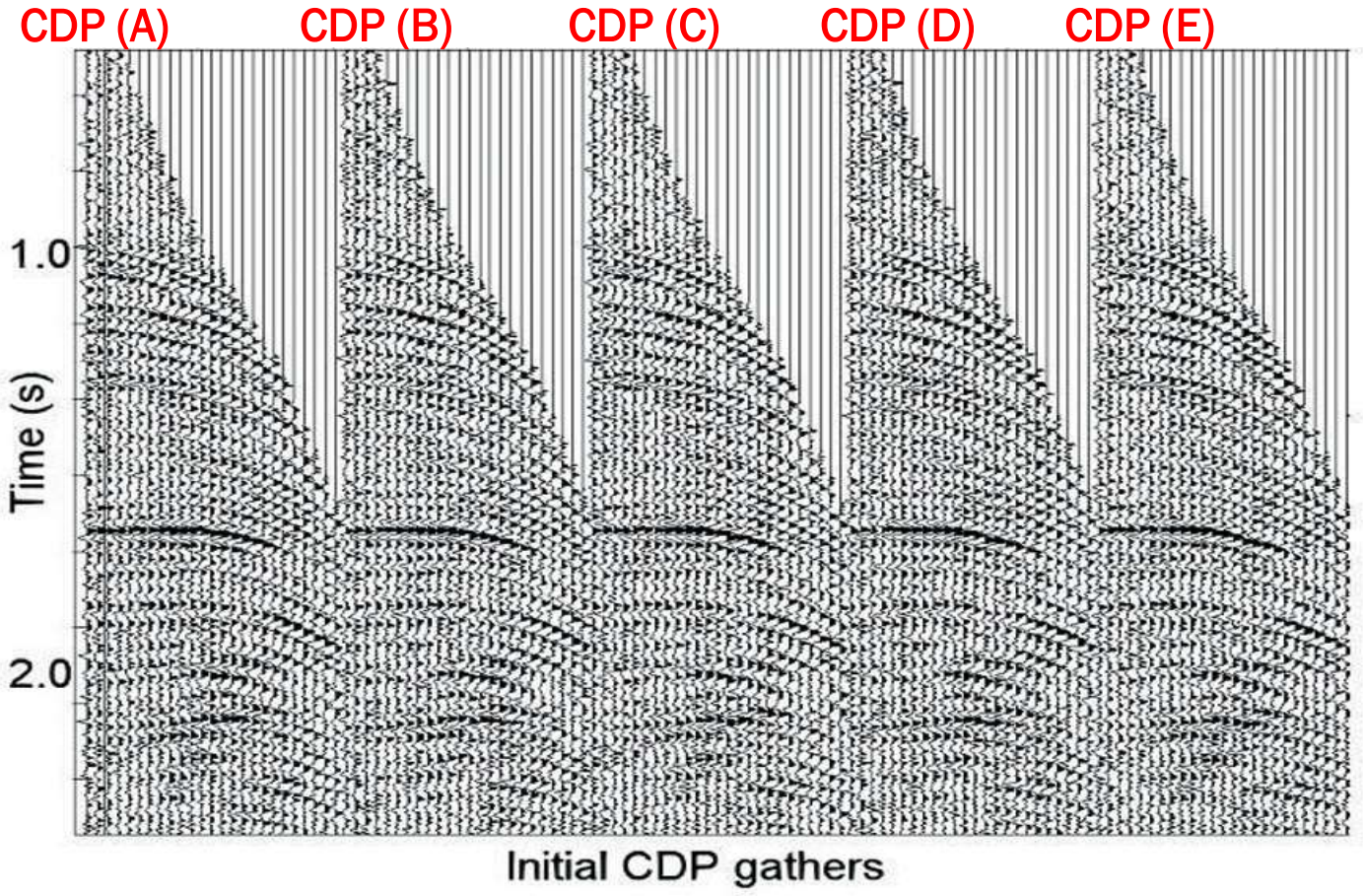
CDP Gathering

- In this stage all the traces coming from the same CDP are sorted in the same display .



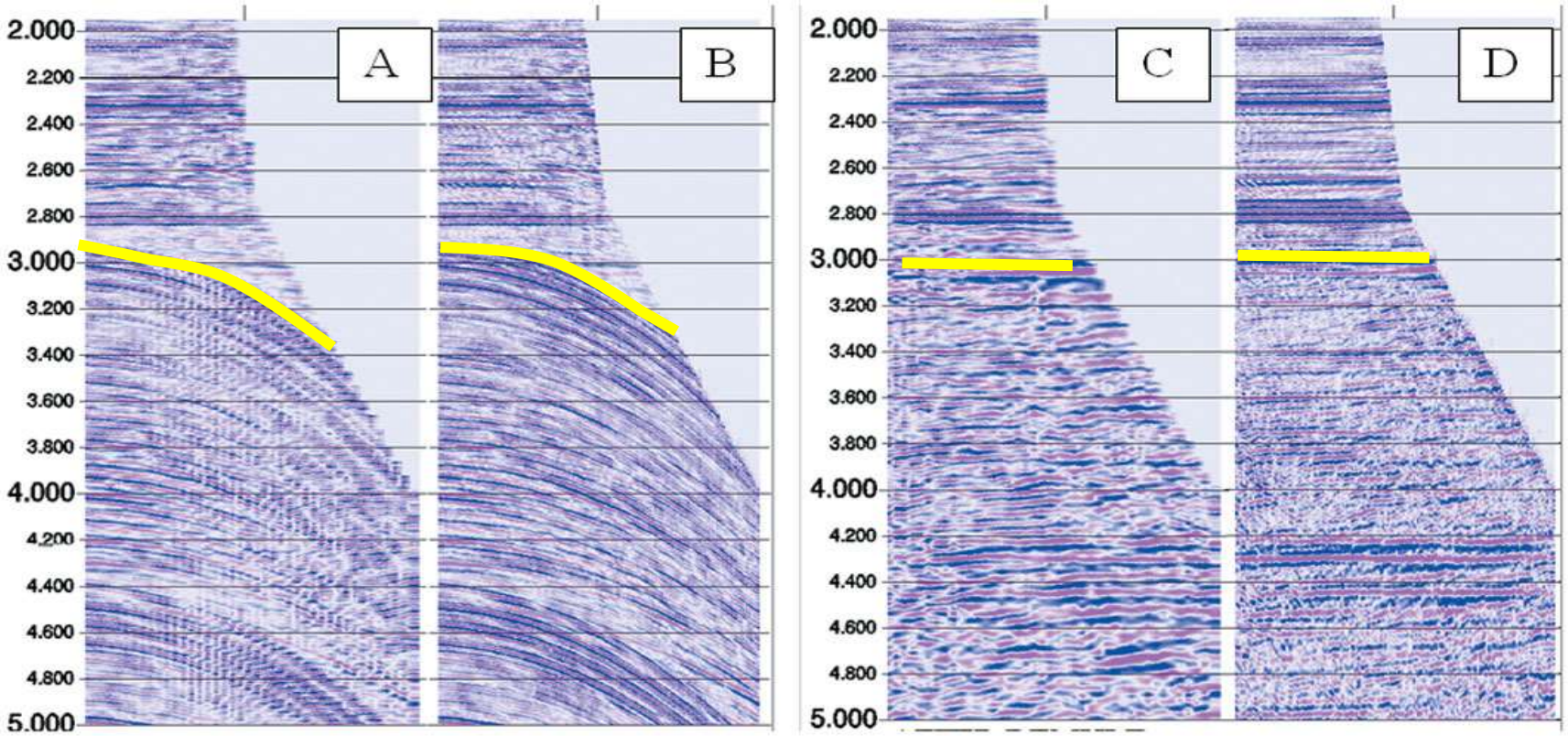
CDP Gathering

- In common depth point gathering all the shots corresponding to the same CDP are collected together.



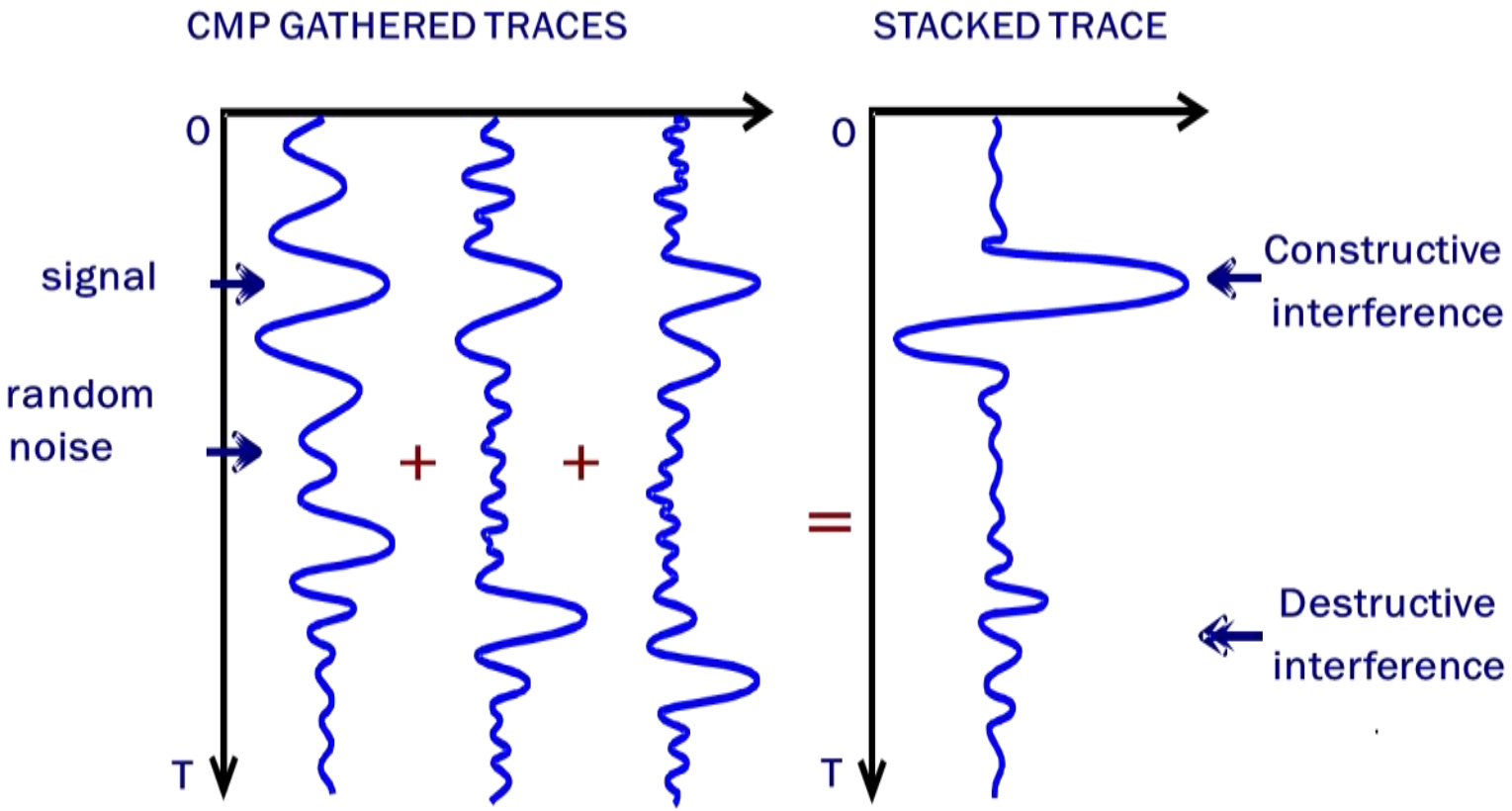
Normal Move Out Correction

- More time needed to reach distant receivers so the data look like a curve.
- Correcting for normal move out restores the curve to a near horizontal display.



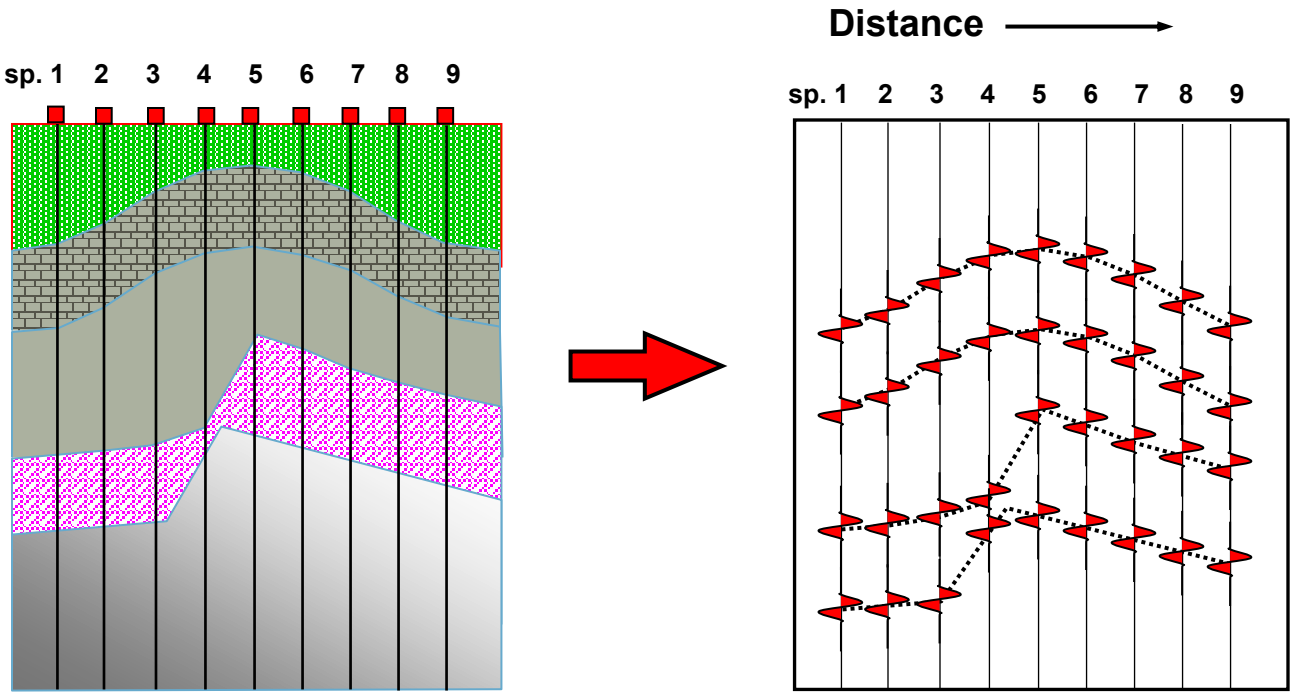
Stacking

- In this stage after the NMO correction all the CDP Gathers are added into one trace, in this case the major events will be amplified (Constructive interference) where the random noise will face destructive interference.



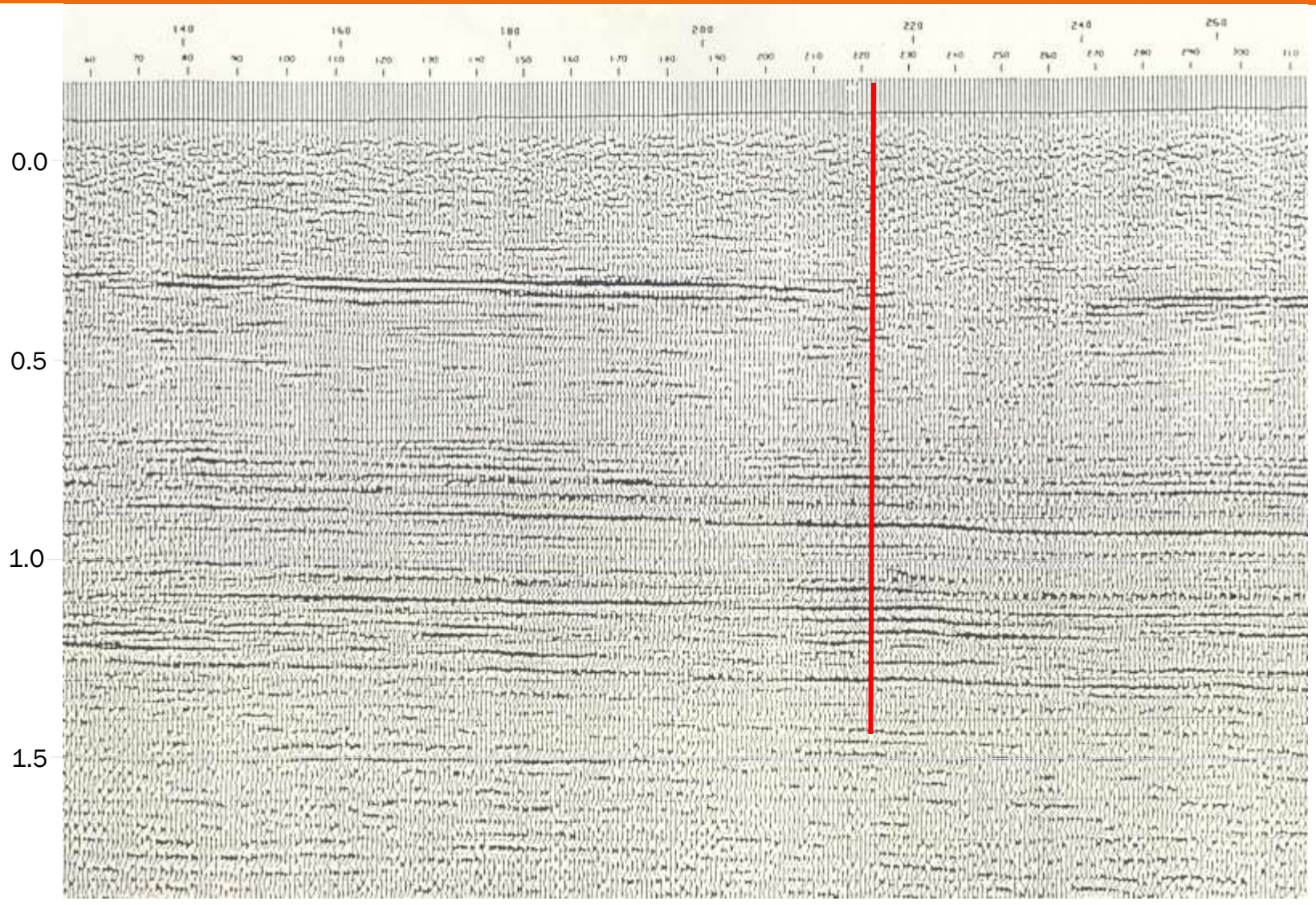
Seismic interpretation & Subsurface Mapping

Seismic Reflection Profiling

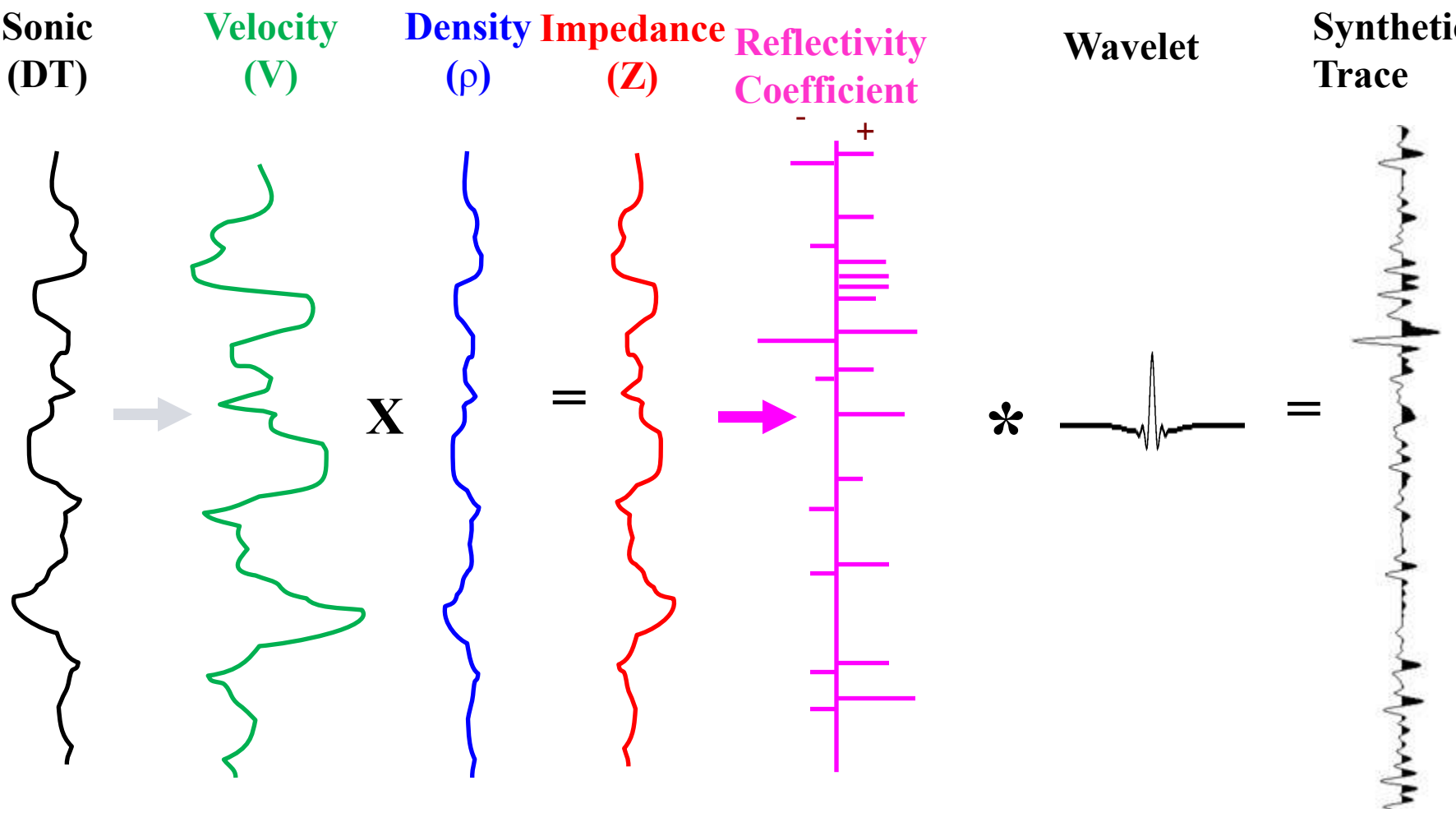


Geological model **Seismic profile**

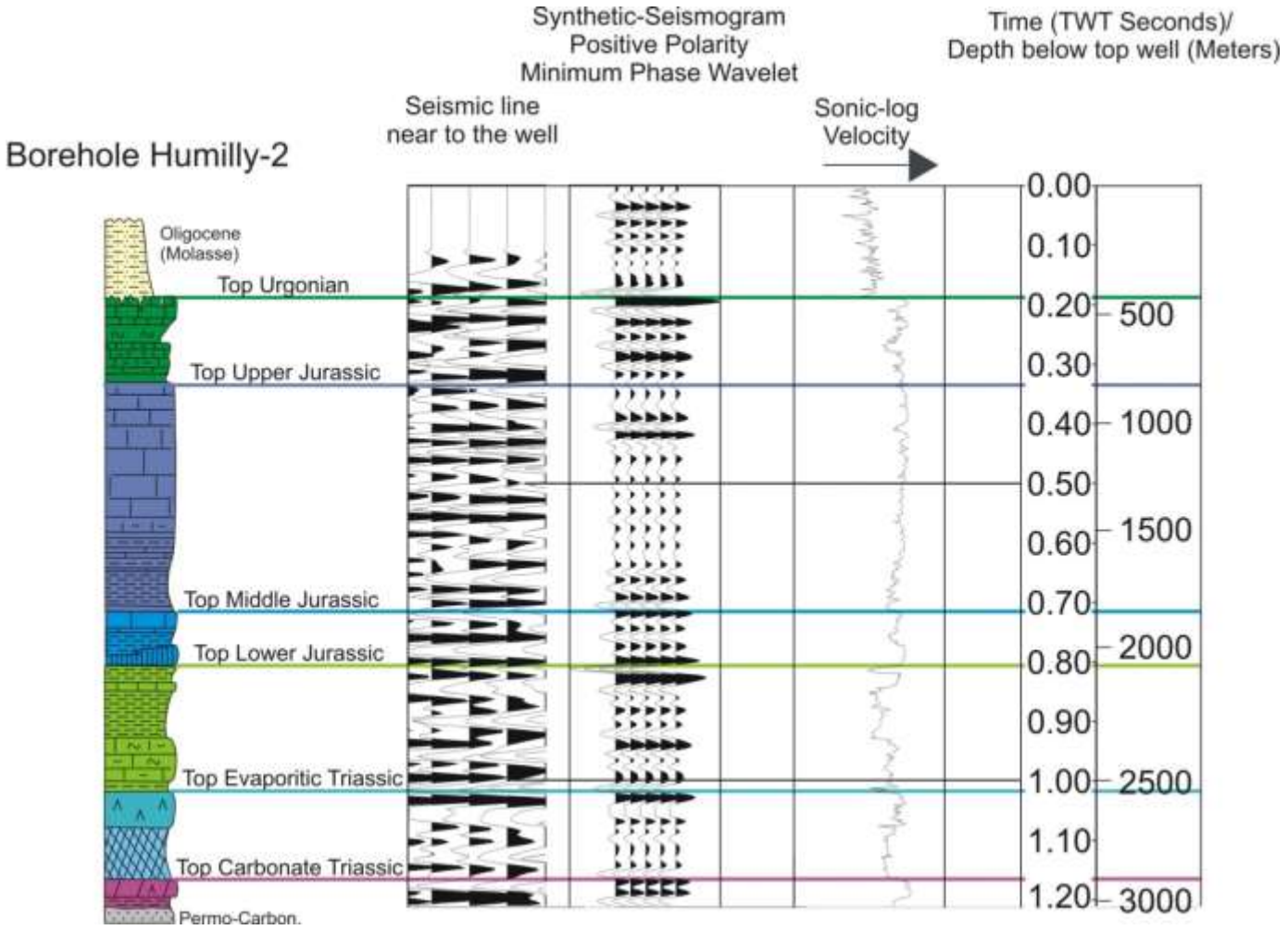
Calibration Of Seismic Profile With Synthetic



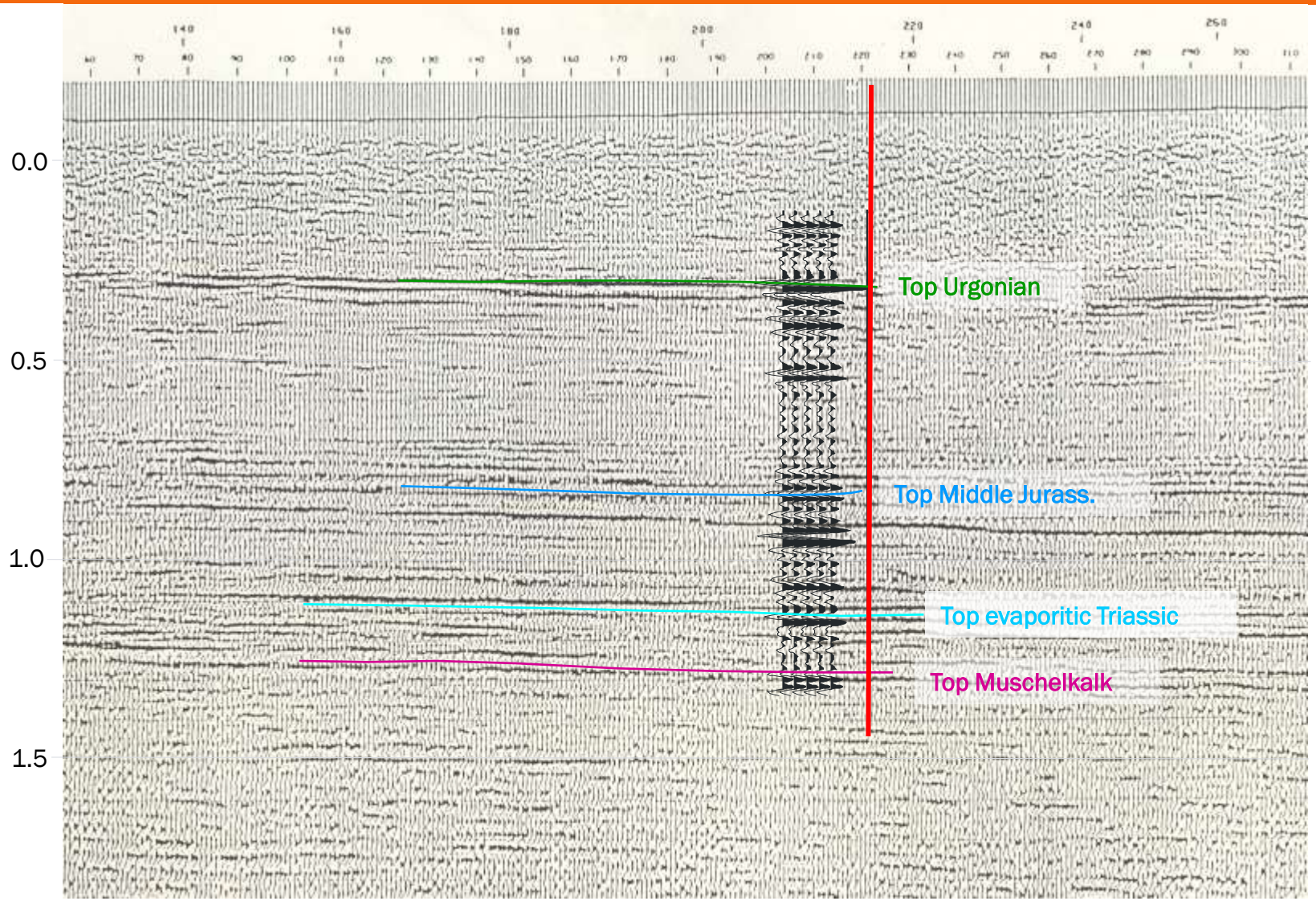
Generation Of Synthetic Seismic Trace



Synthetic Seismogram

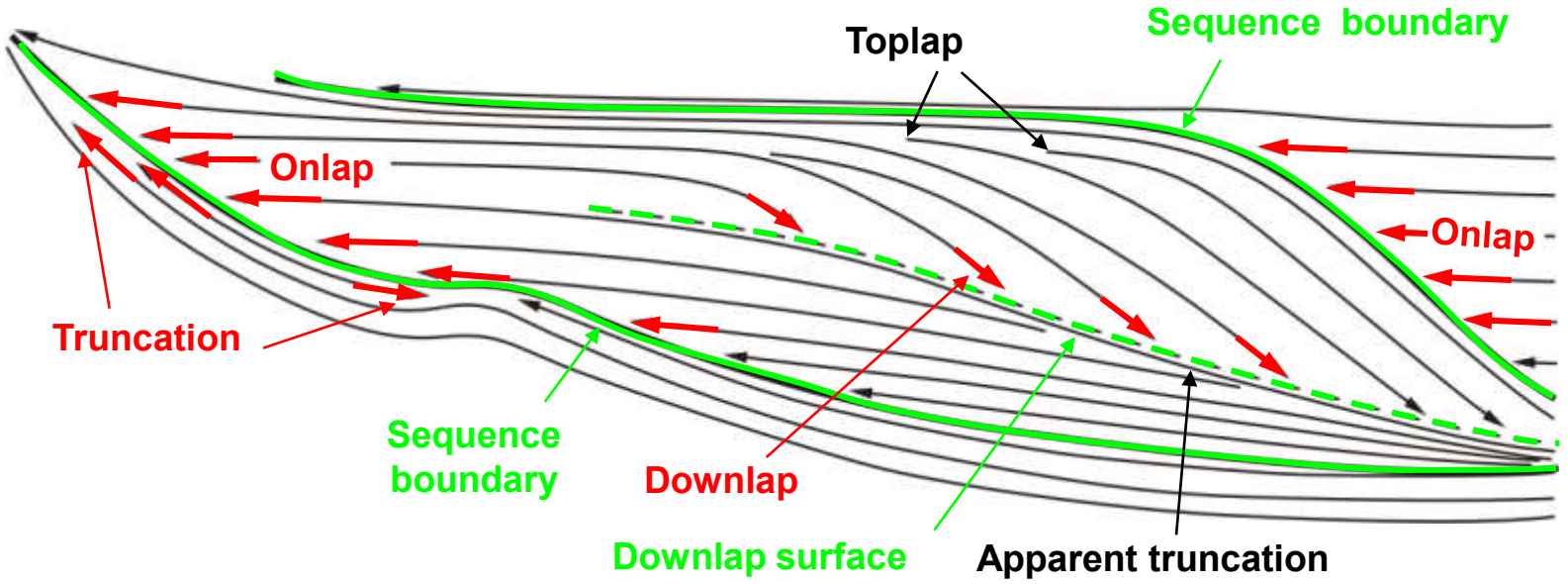


Calibration Of Seismic Profile With Synthetic



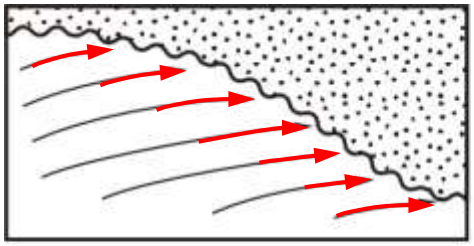
Stratigrafic Interpretation

- This kind of interpretation requires a great knowledge about:
  - Different Depositional Environments.
  - Sea level and shoreline status.
  - The facies feeding of each environment.
  - Detection of unconformities.

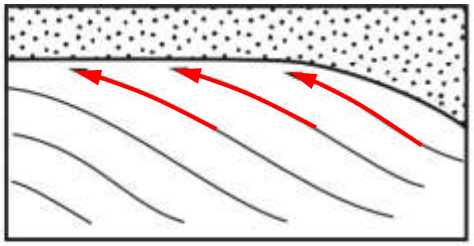


Relation Between Strata And Limits Of Depositional Sequences

UPPER LIMIT

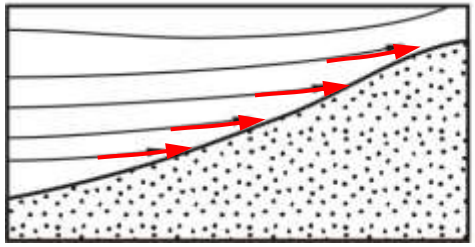


Erosional truncation

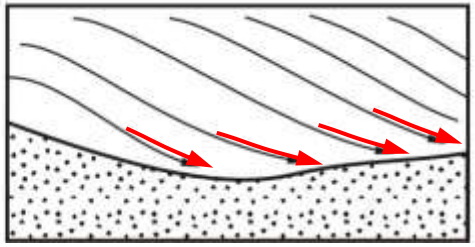


Toplap

LOWER LIMIT

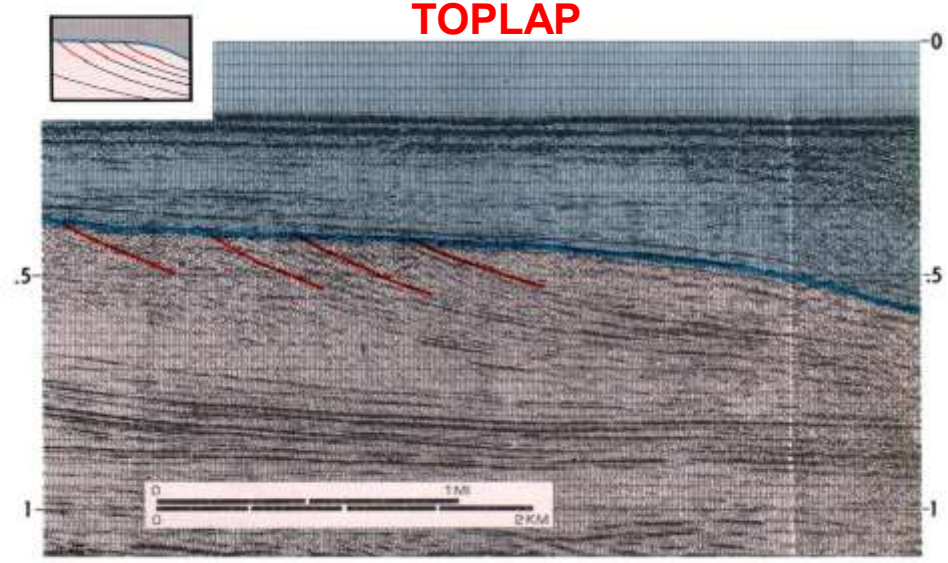


Onlap

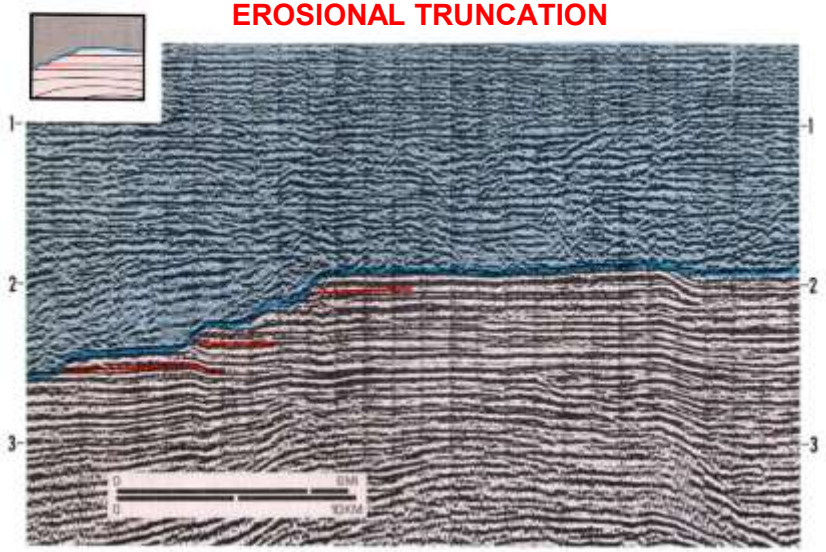


Downlap

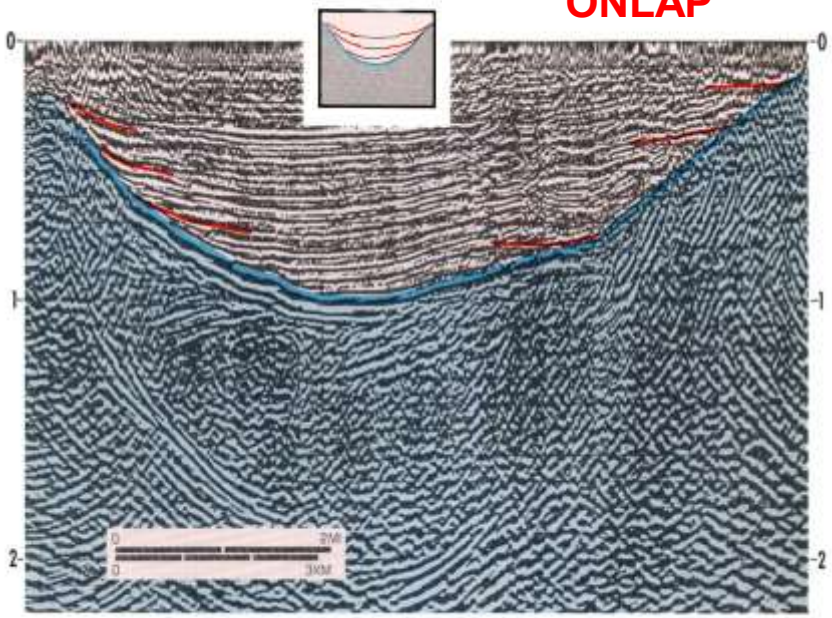
TOPLAP



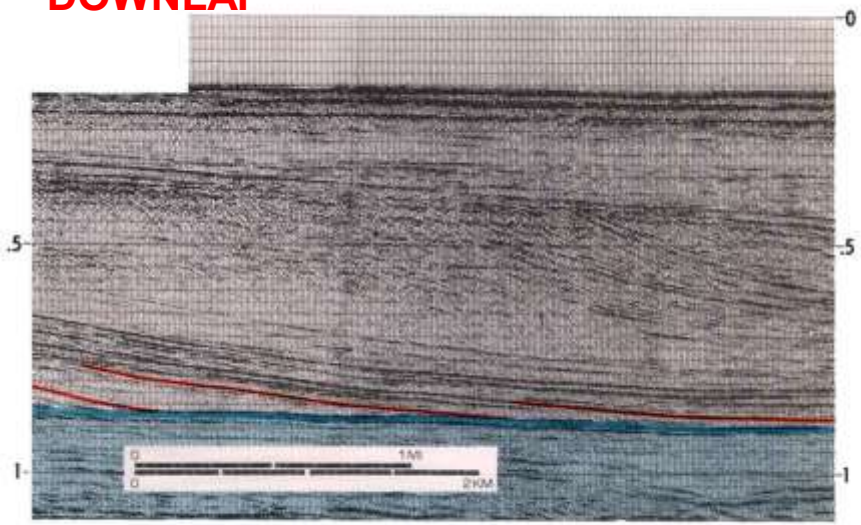
EROSIONAL TRUNCATION



ONLAP

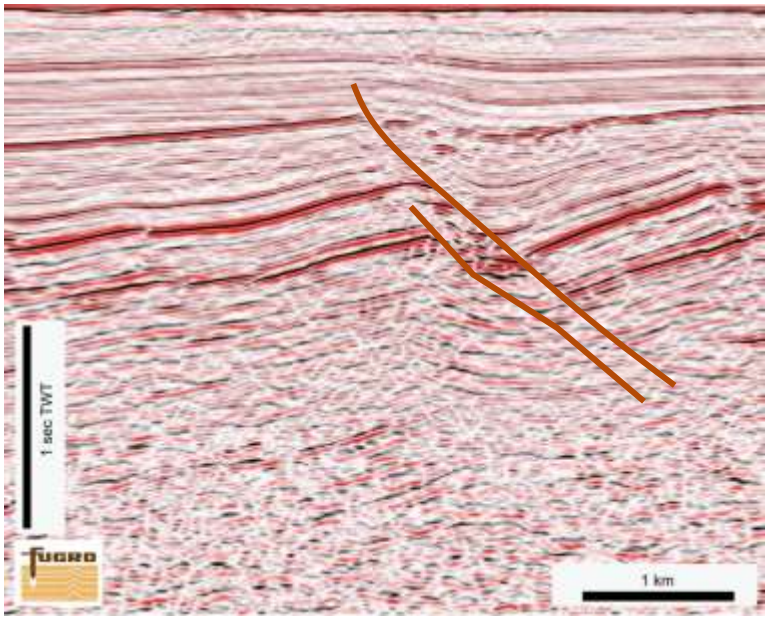


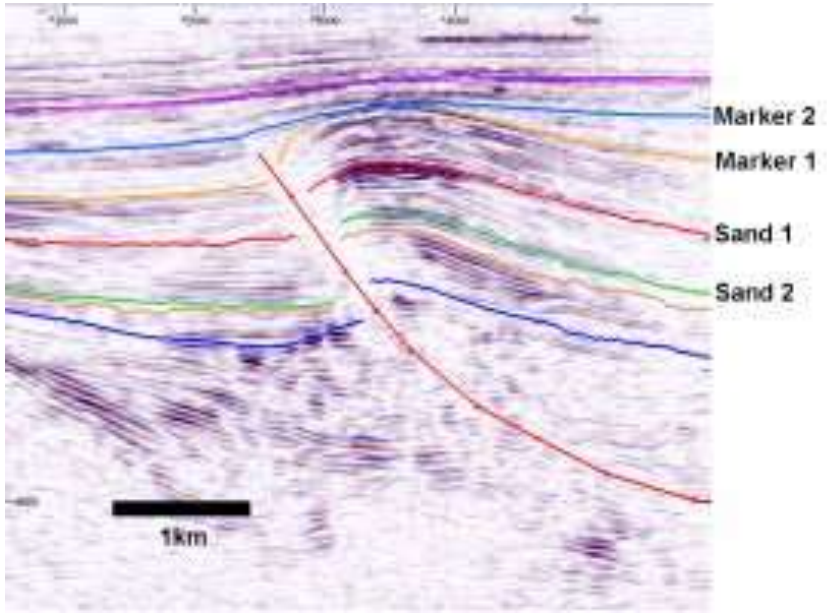
DOWNLAP



Structural Interpretation

- This kind of interpretation requires knowledge of:
- The tectonic framework of the area.
- Variation of thicknesses of the same layer along the area.
- Normal and Reverse faults detection on seismic lines.





Exploration & Development

$$STOOIP = \frac{7758\ V_b\ \phi\ \ (1 - S_w)}{B_{oi}}$$

STOIP : Standard Tank Oil In Place	(bbl)
Vb: Bulk Volume where (Vb = A . h.)	(acre-ft)
A: Area of the Trap	(acre)
h : Vertical Closure of the Trap	(ft)
Ø: effective Porosity	(fraction)
Sw: Water Saturation.	(fraction)
Boi: Formation Volume factor.	

$$B_{oi} = 1.05 + (N\ .\ 0.05)$$

N is the number of hundreds of ft^3 of gas produced per bbl of oil [for example, in a well with a GOR of 1000, B_{oi} = 1.05 + (10 × 0.05) = 1.55

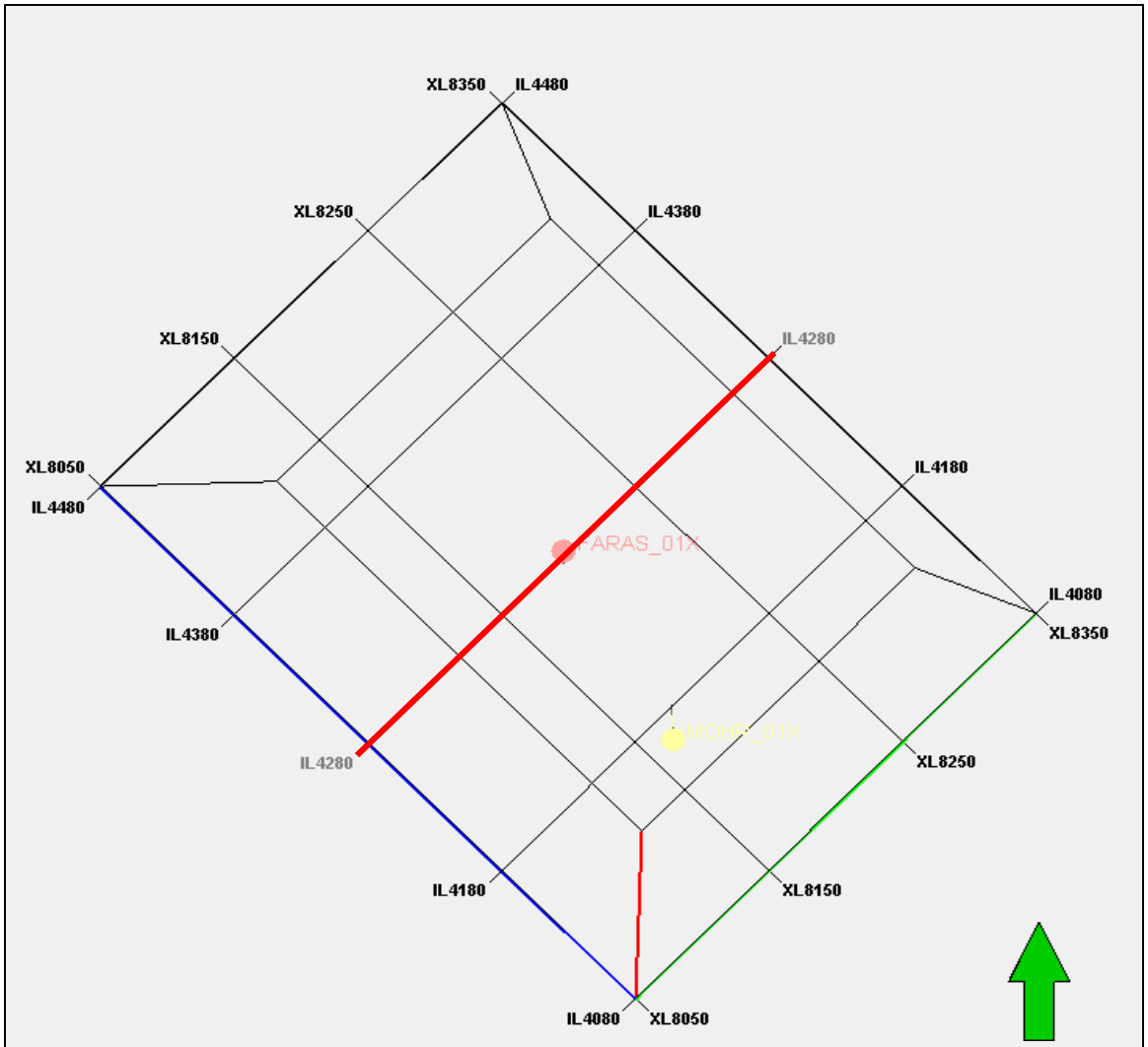
Subsurface Mapping

Subsurface mapping can be done in 5 stages:

- Interpreting all seismic lines covers the area.
- Tie seismic lines that crossing each other.
- Detecting the Fault heaves and drawing the fault polygon
- Pick the TWT of your horizon in each line.
- Contour the picked TWT.

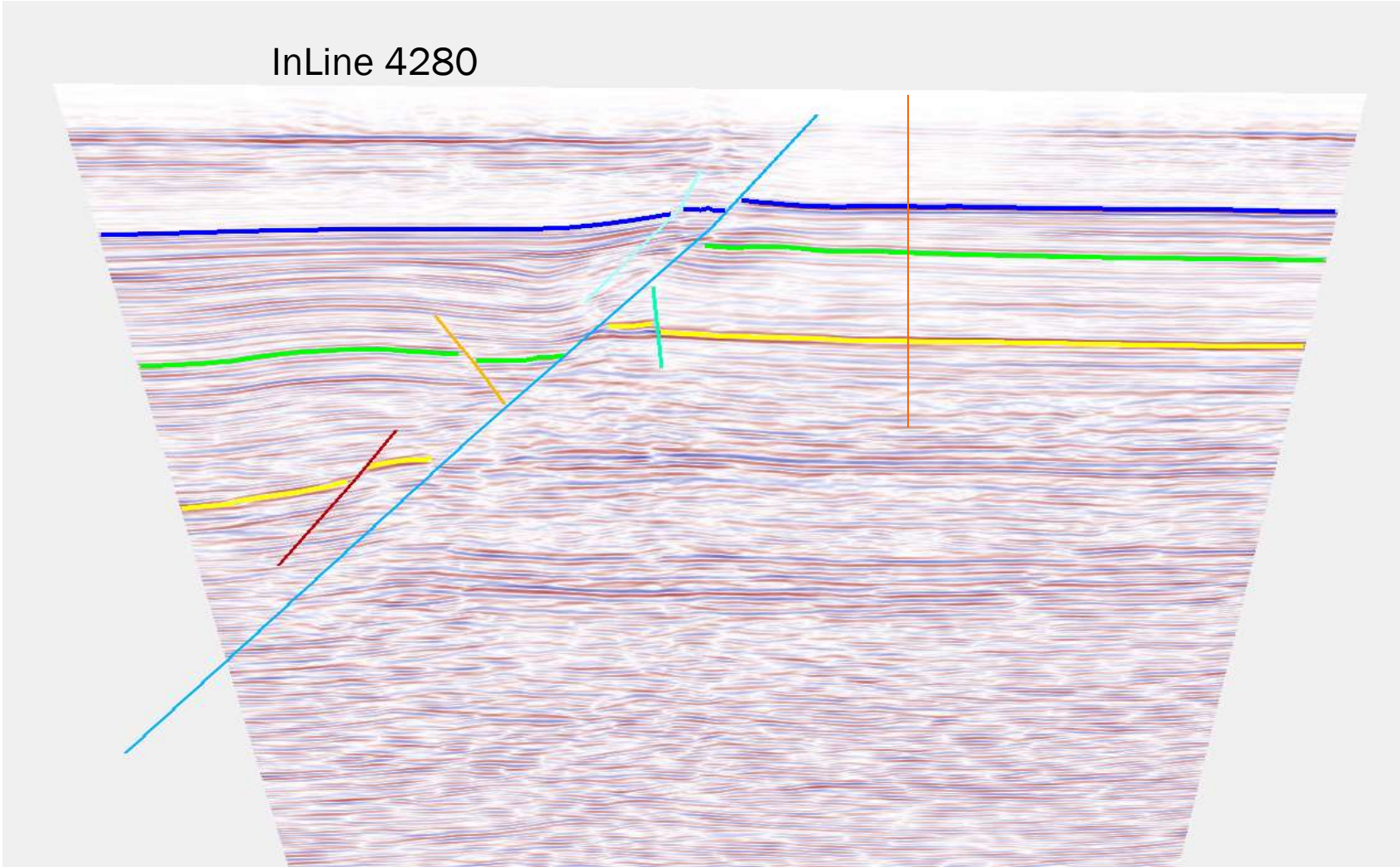
Interpret Seismic Lines

- Select an Inline crossing a well



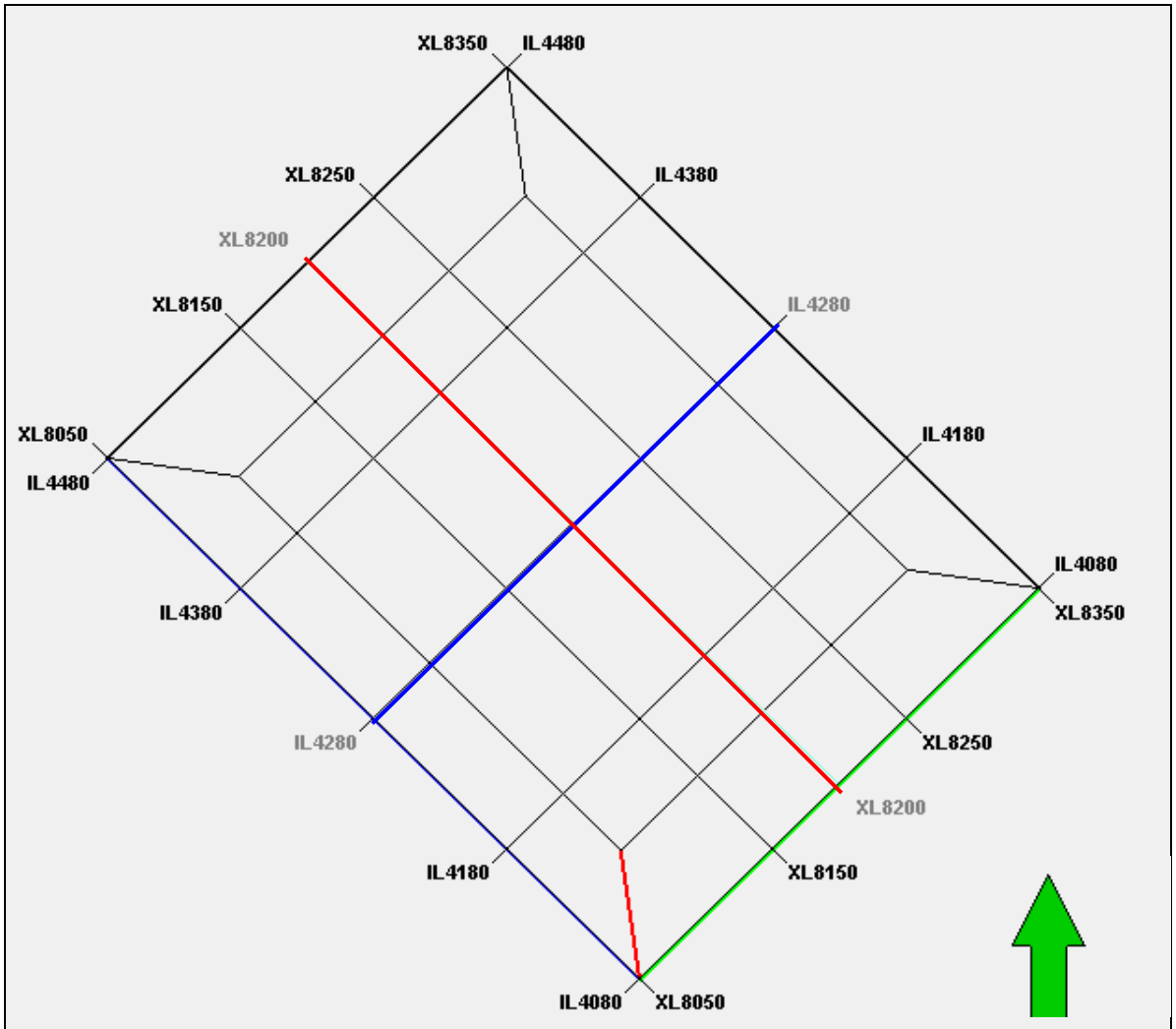
Interpret Seismic Lines

- Interpret the main horizons and main faults



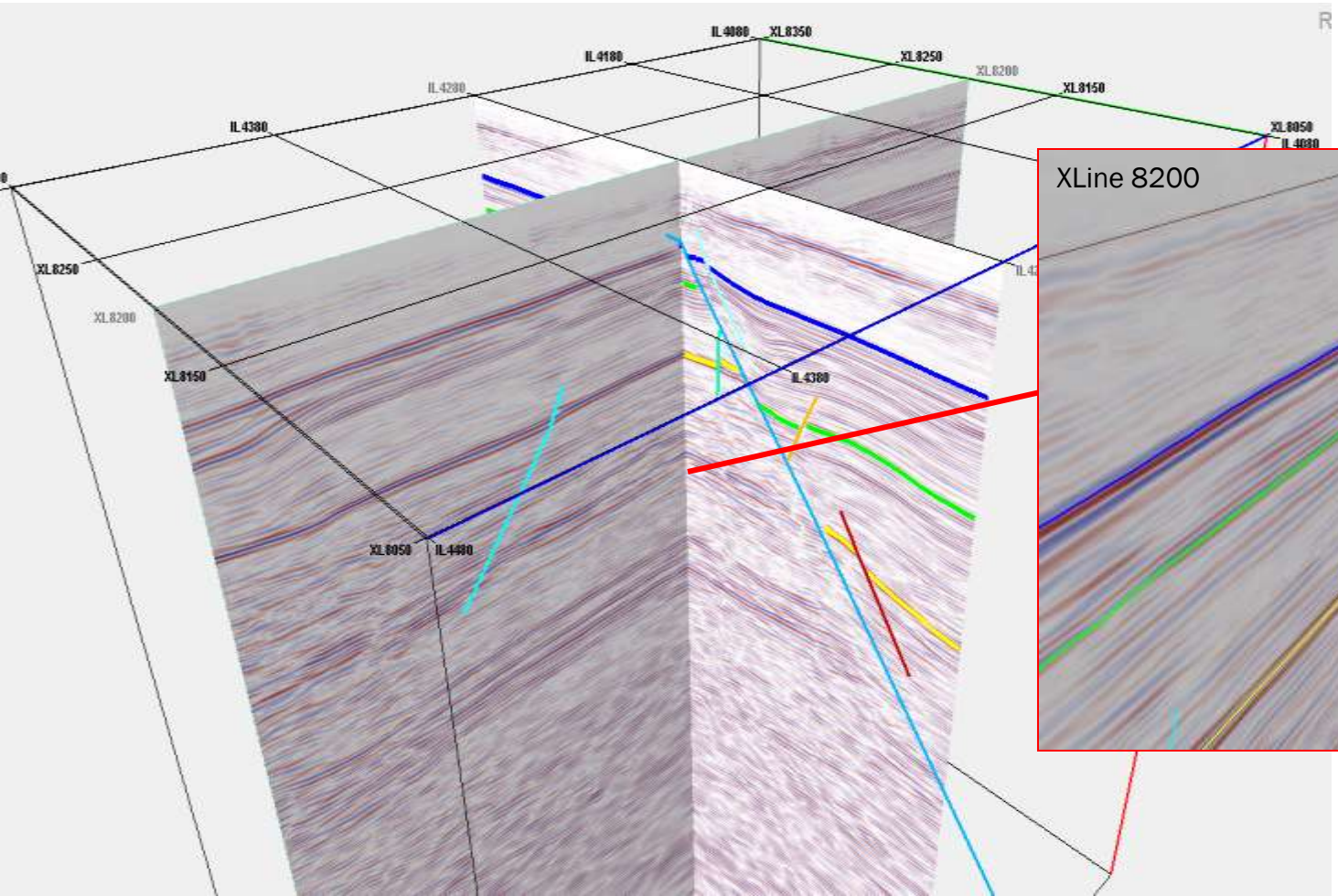
Tie Seismic Lines

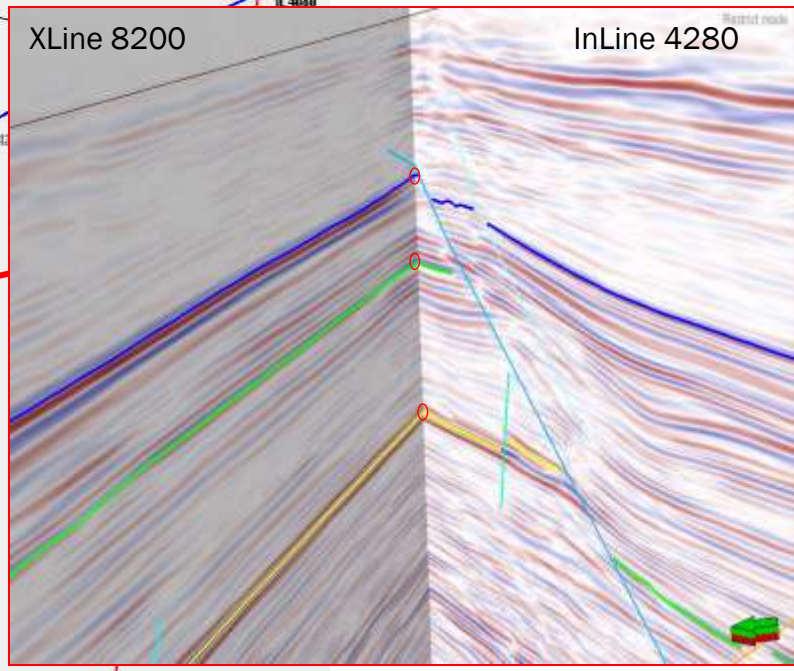
- Now select an Xline that crossing the Inline you interpreted



Tie Seismic Lines

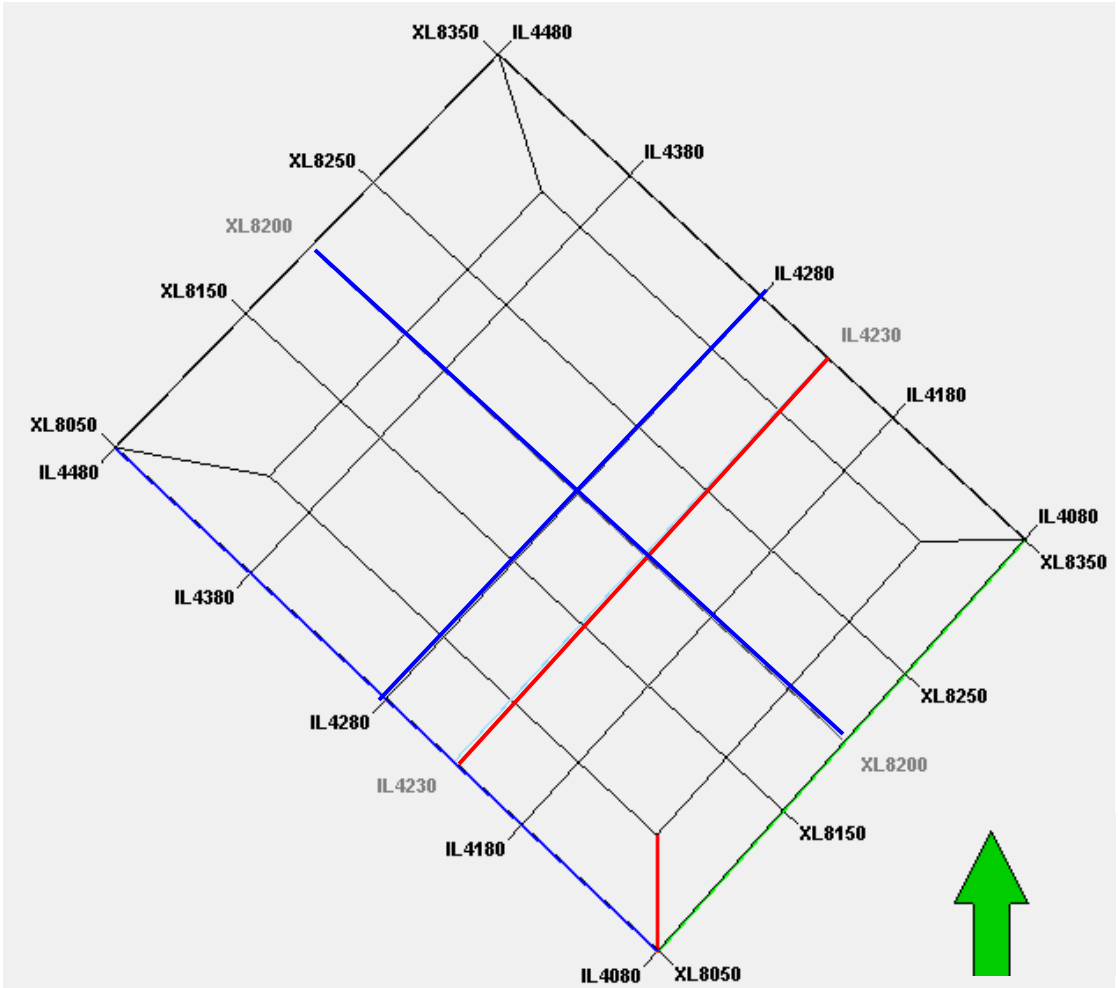
- Now realize the cross posts of the interpreted horizons on the Xline is visible so you can easily track them like shown.



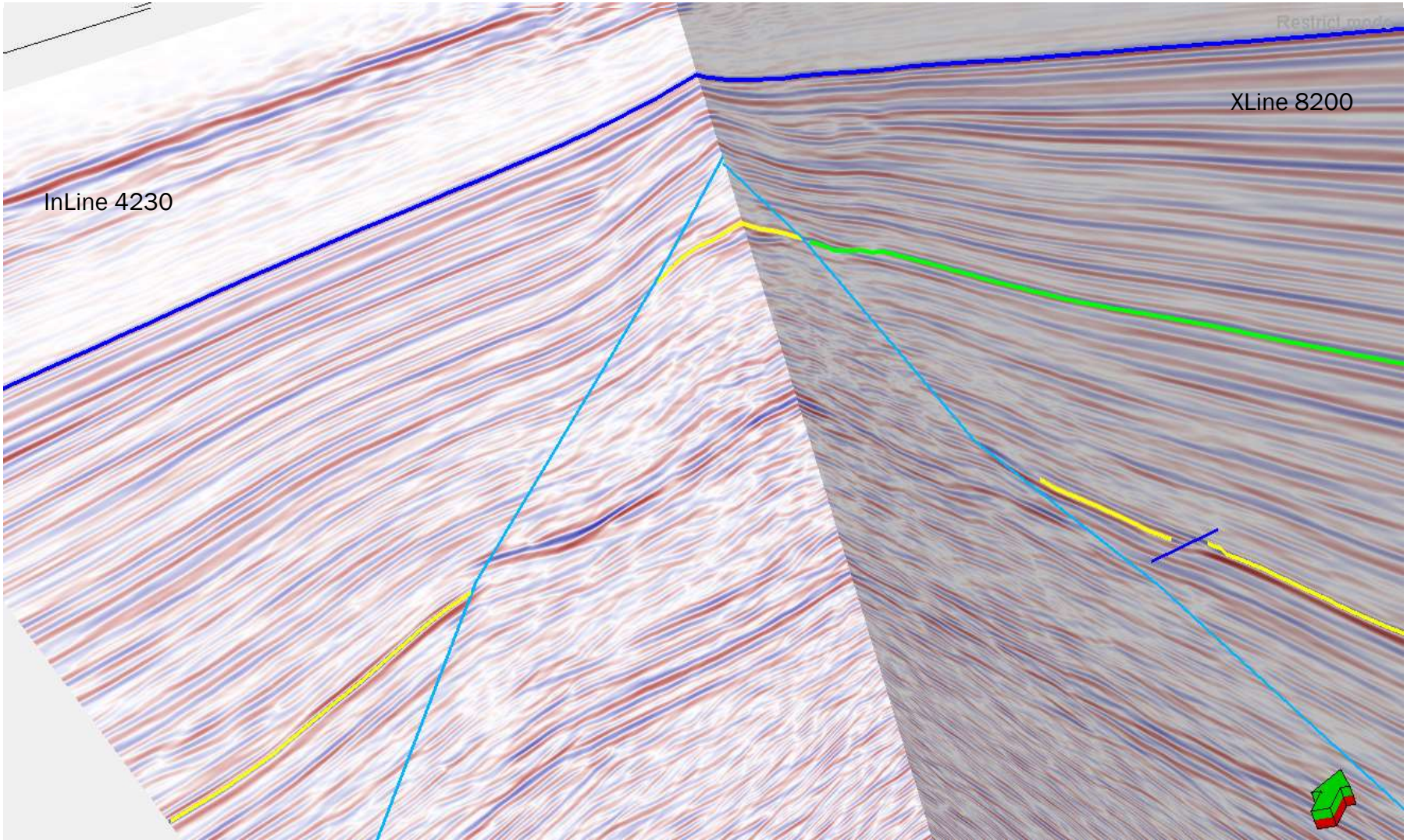


Tie Seismic Lines

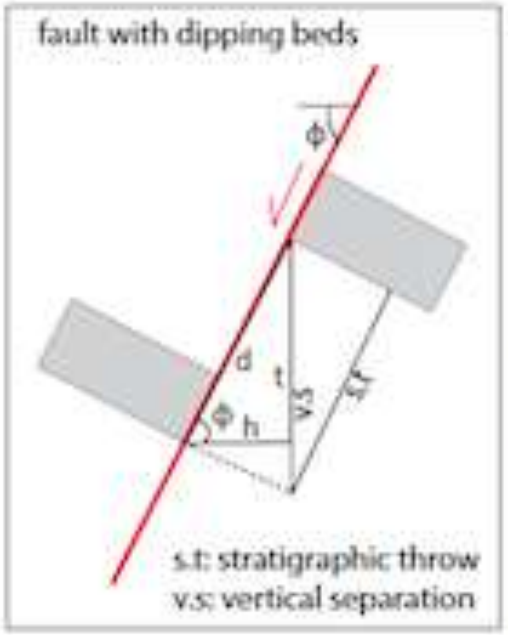
- Now we continue by selecting another Inline that crossing the interpreted Xline.

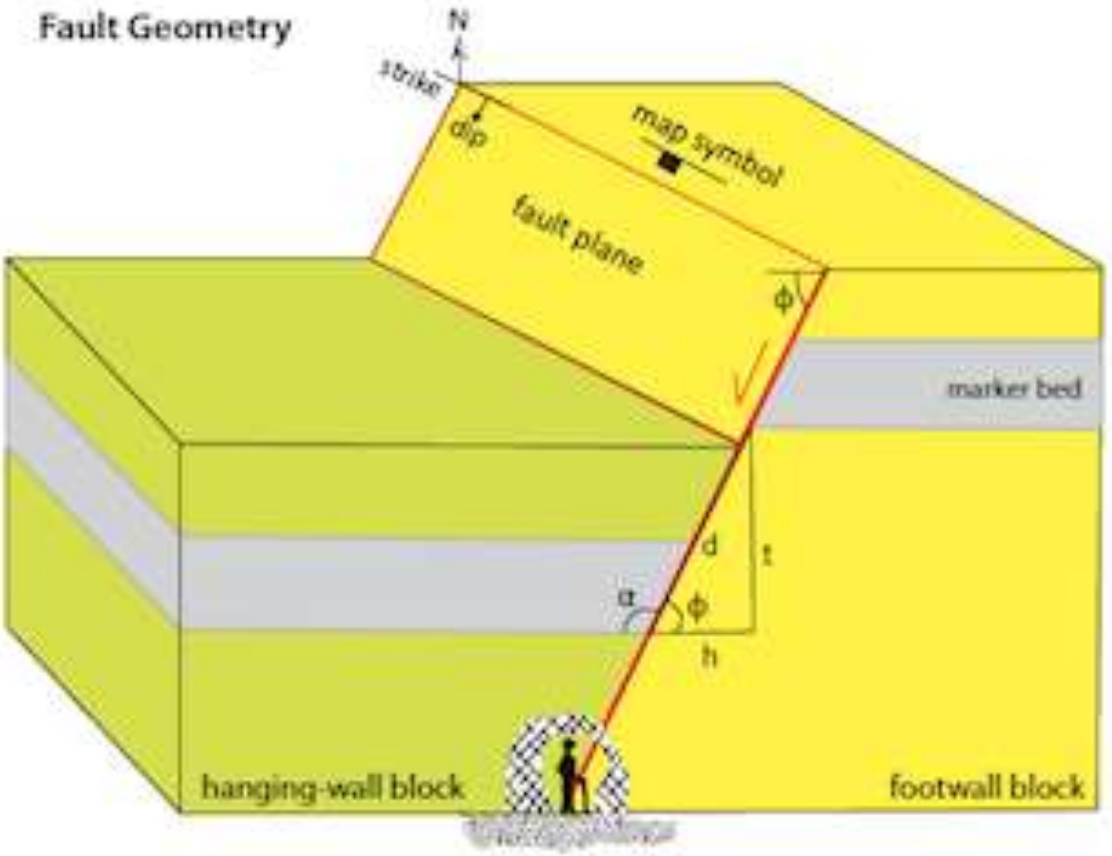


Tie Seismic Lines



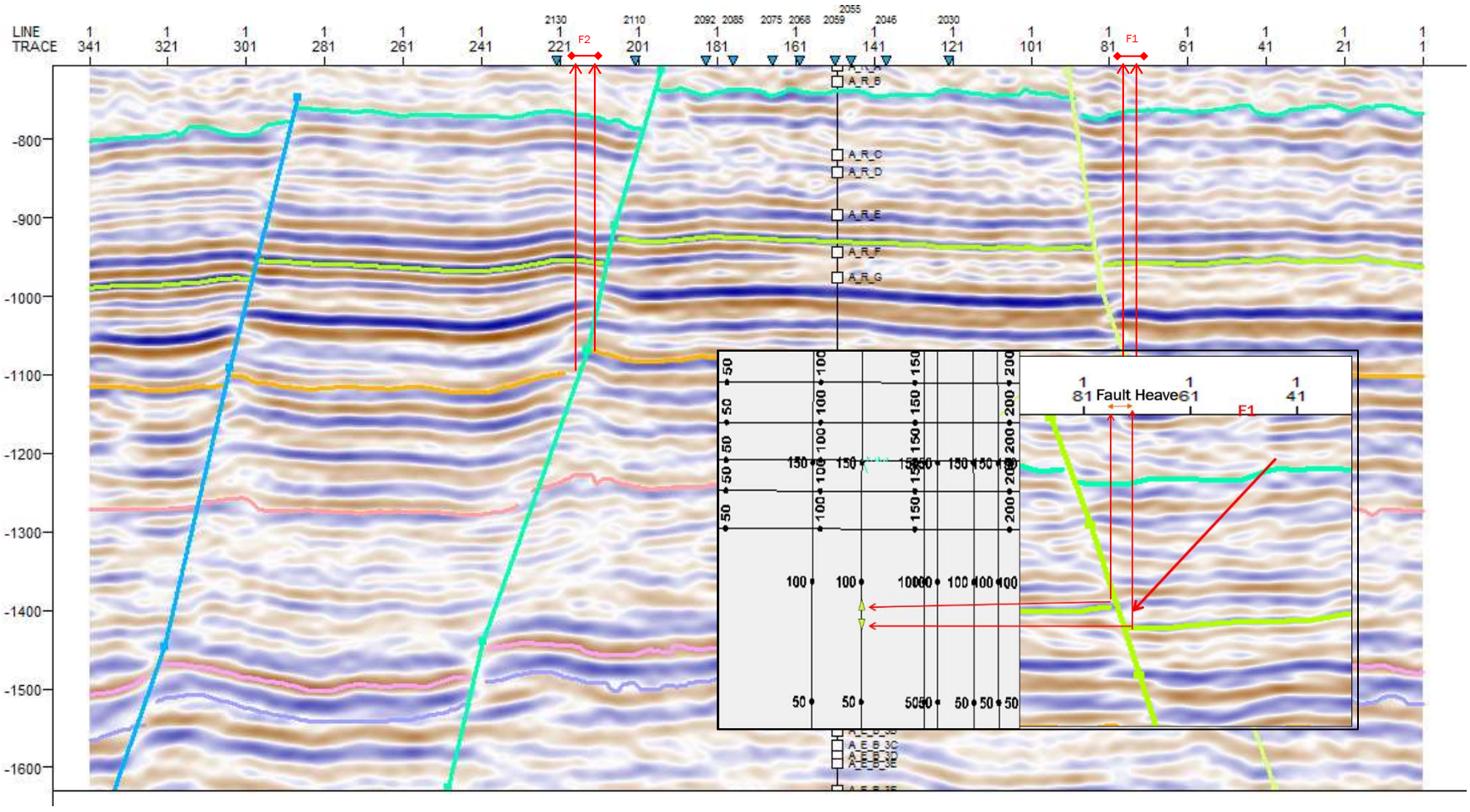
Detection of Fault Heaves



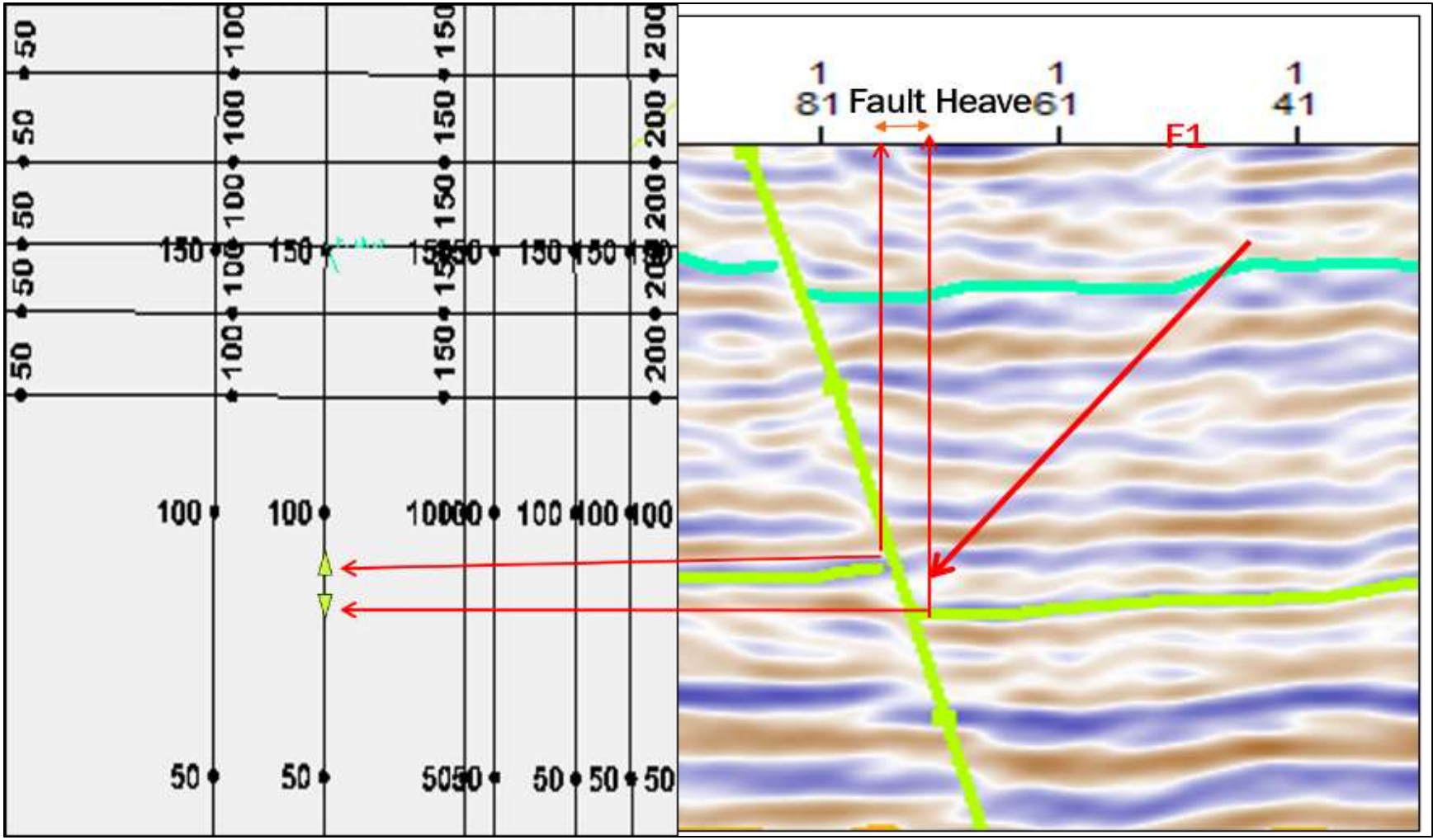


Φ : Fault Angle
d: Fault Displacement
t: Fault Threw
h: Fault Heave

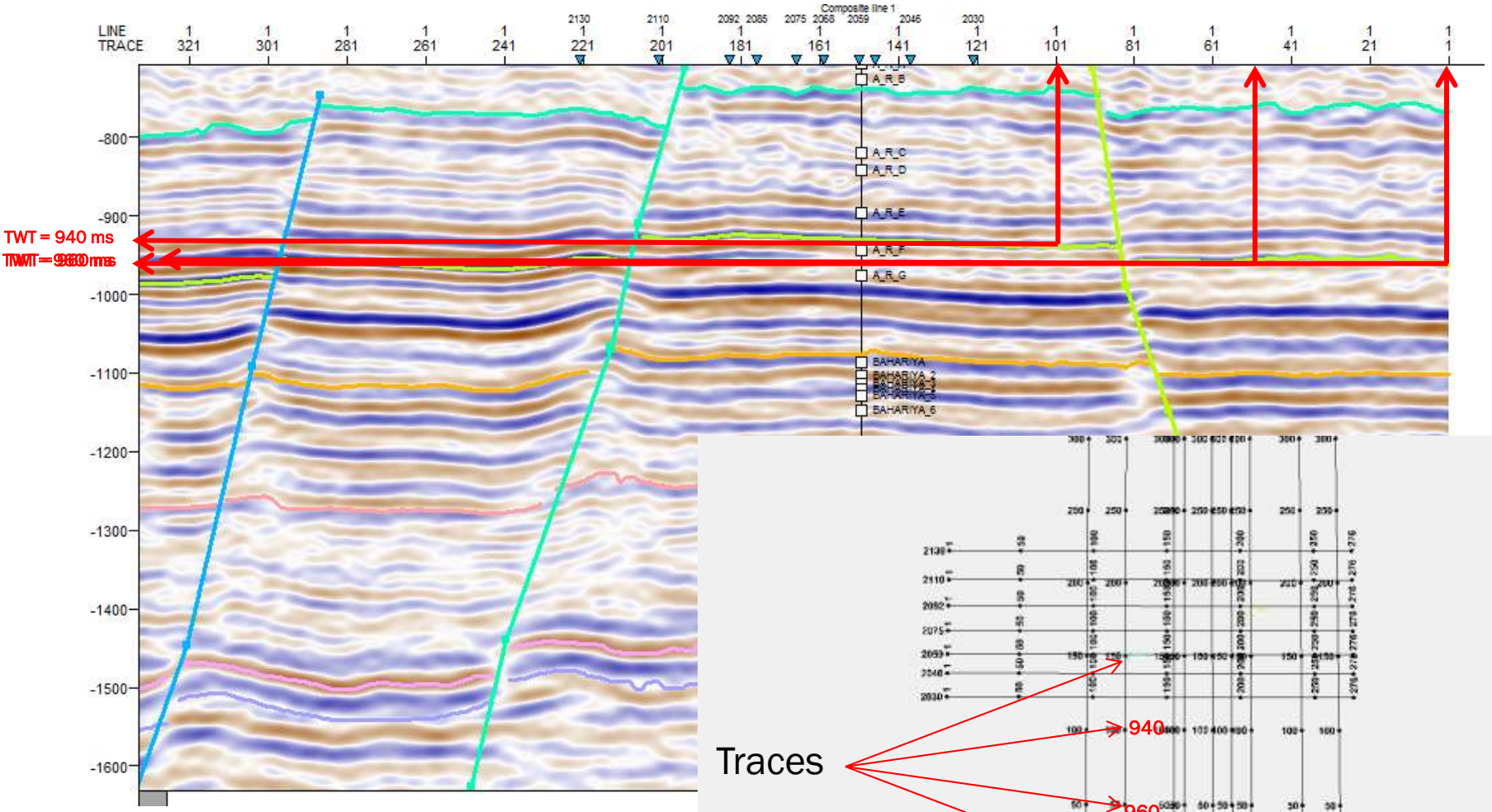
Detection of Fault Heaves

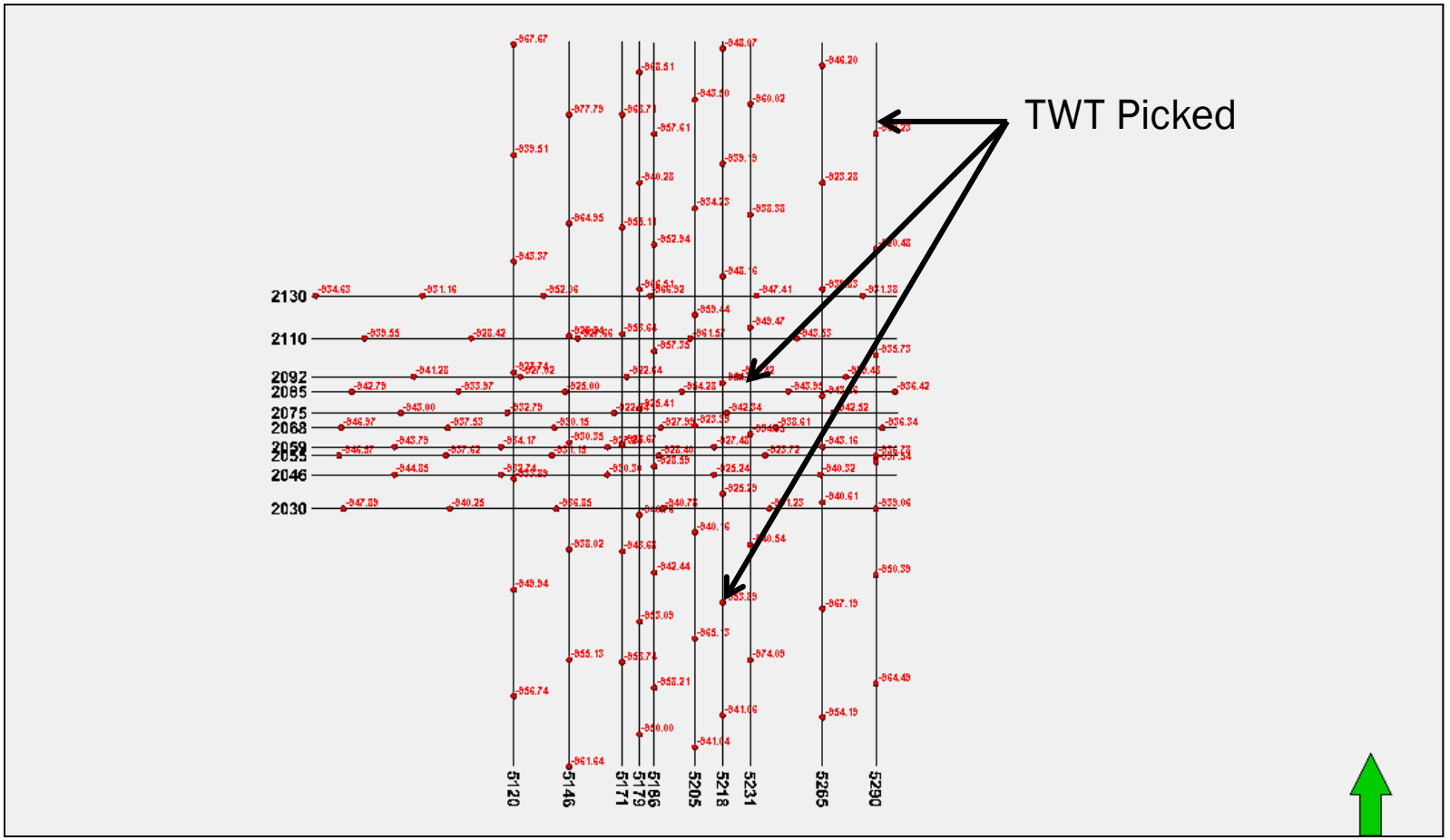


Detection of Fault Heavs

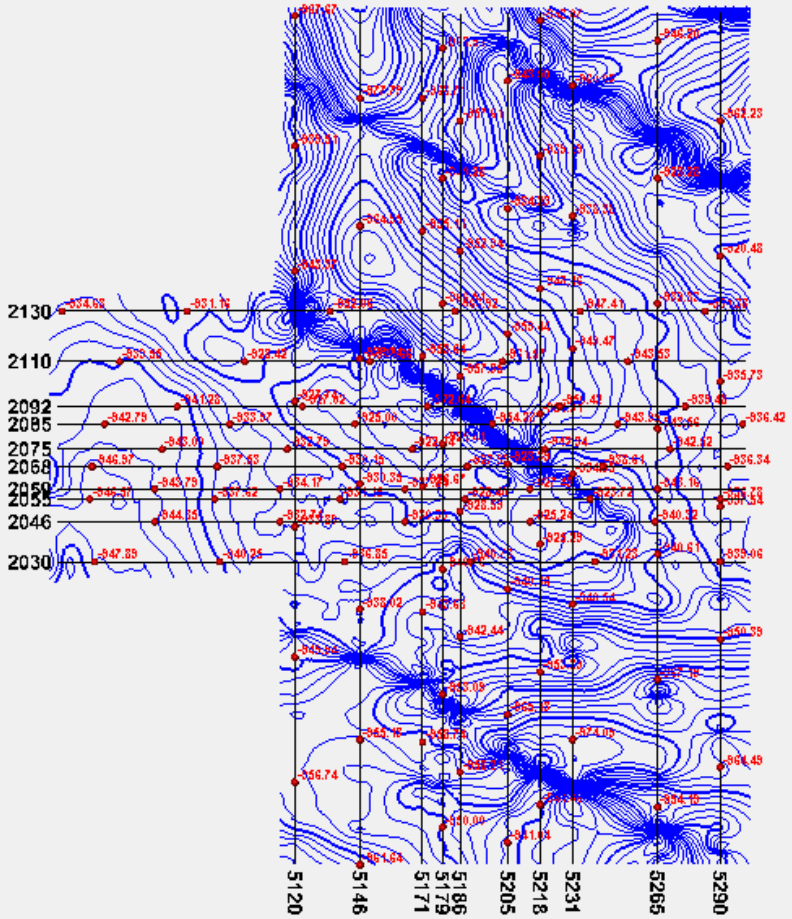


Picking The TWT



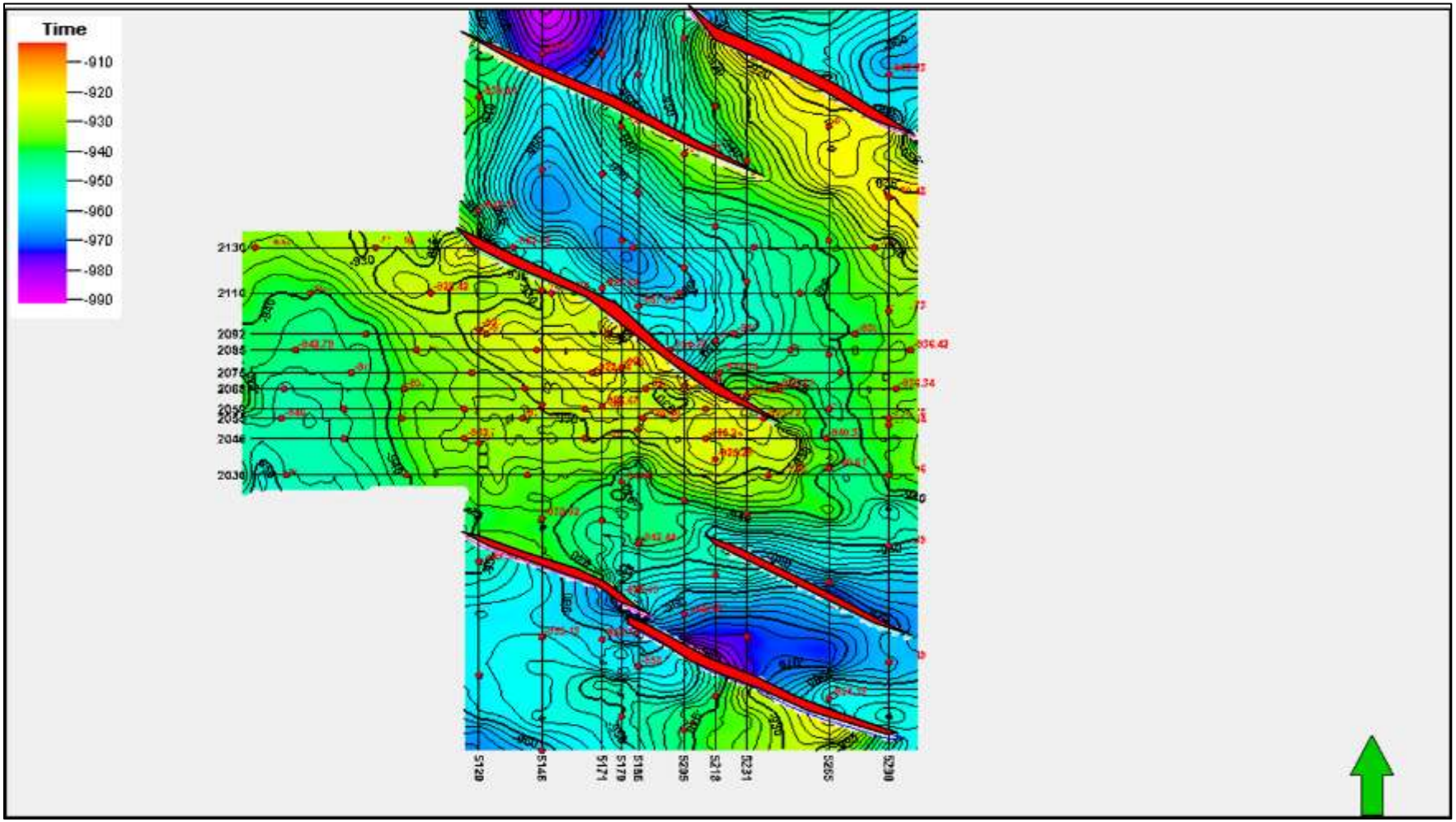

TWT Picked
2130
2110
2092
2085
2075
2068
2059
2055
2046
2030
5120
5146
5171
5179
5186
5205
5218
5231
5265
5290

Contour the TWT Picked



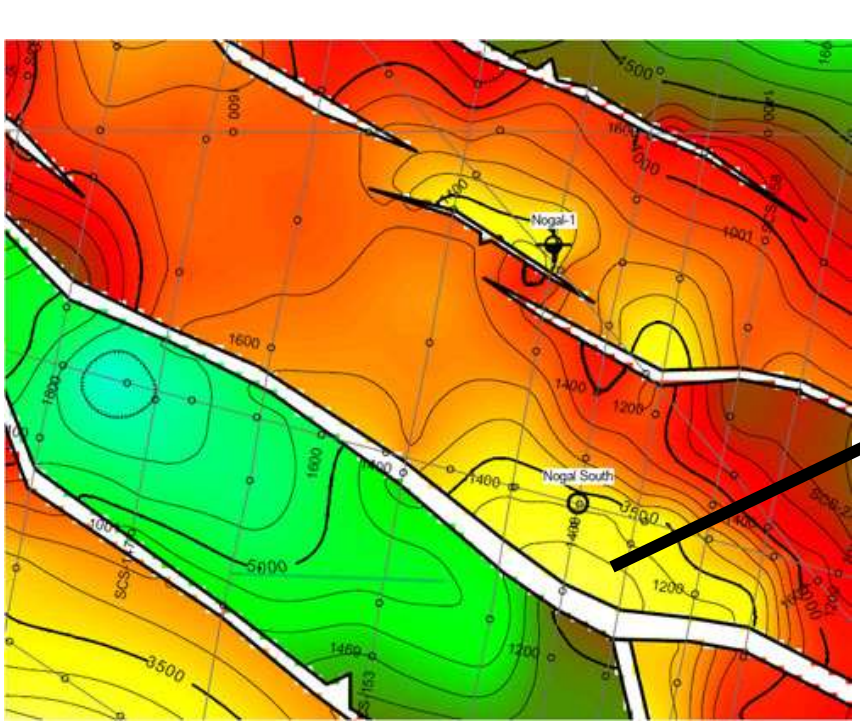
Contour Interval = 5 ms

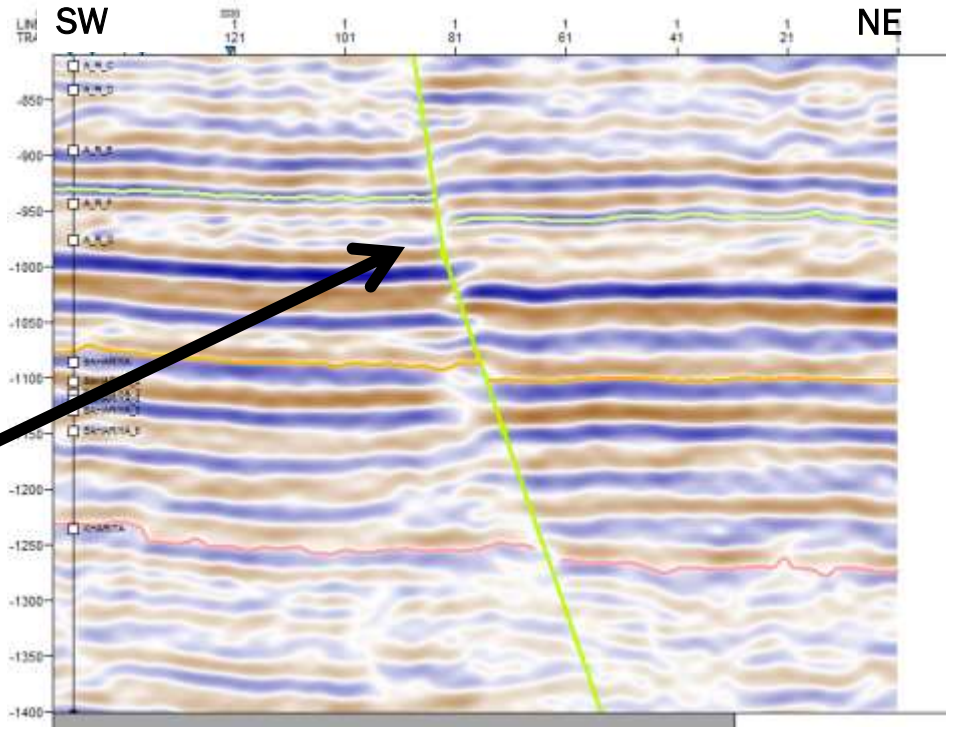
TWT Color Scaling



Types of Structural Traps

- Three Way Dip Closure



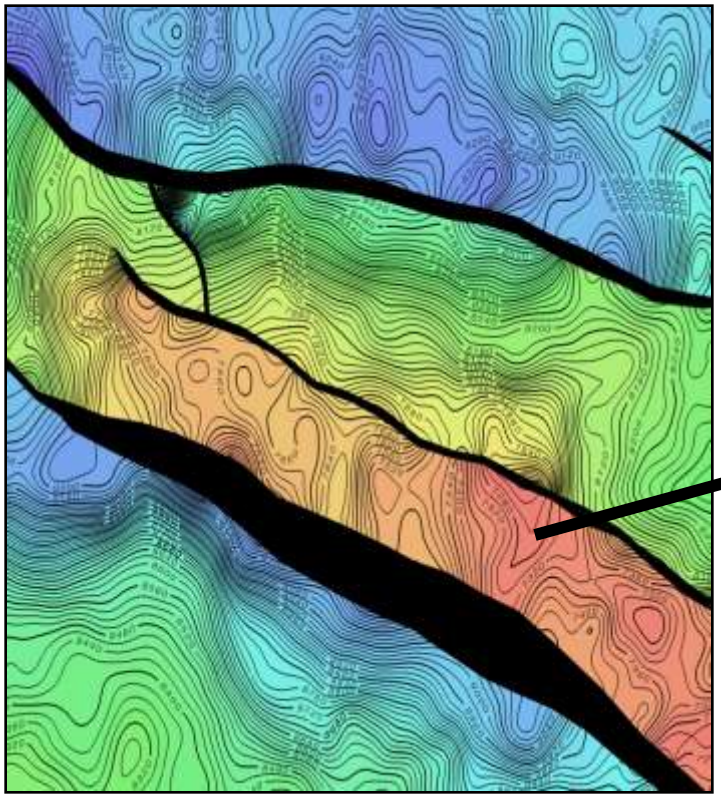


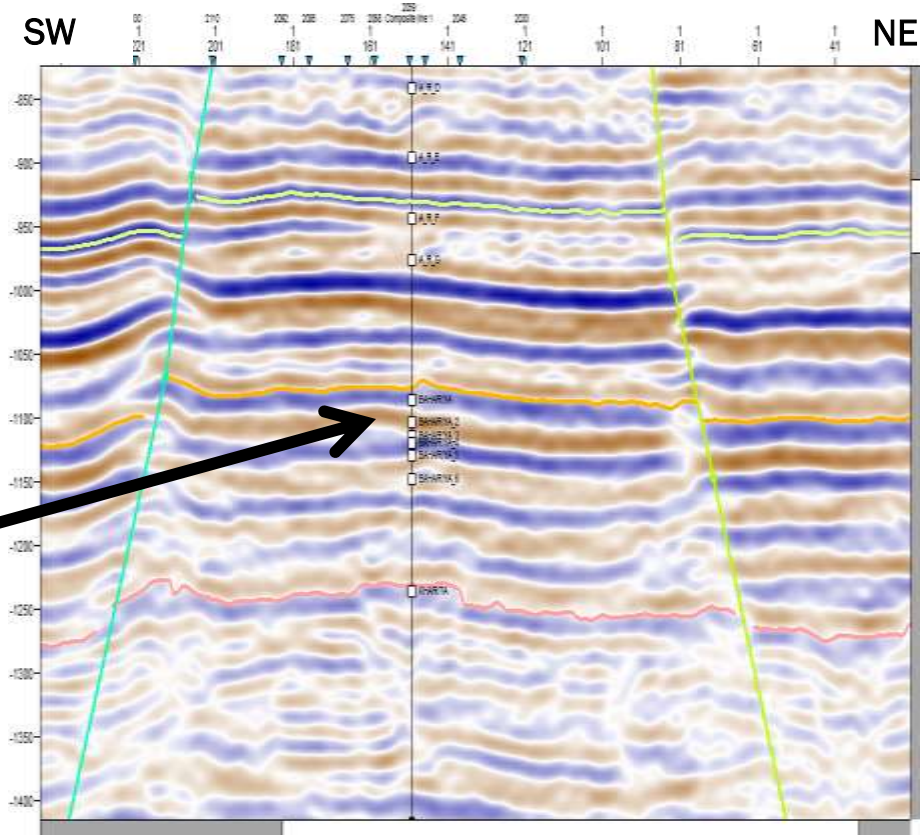
Map View

Seismic View

Types of Structural Traps

- Two Way Dip Closure



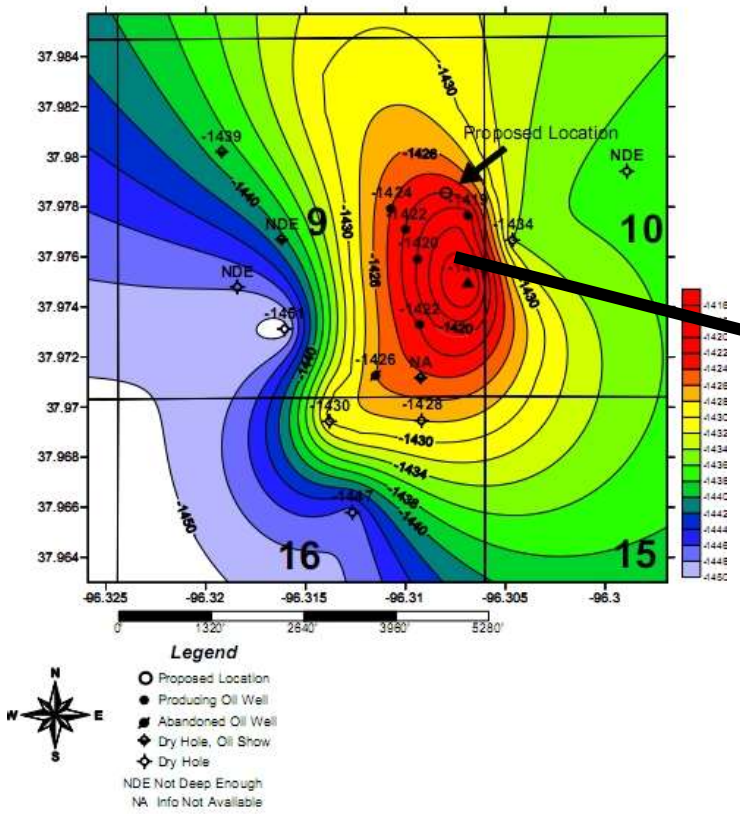


Map View

Seismic View

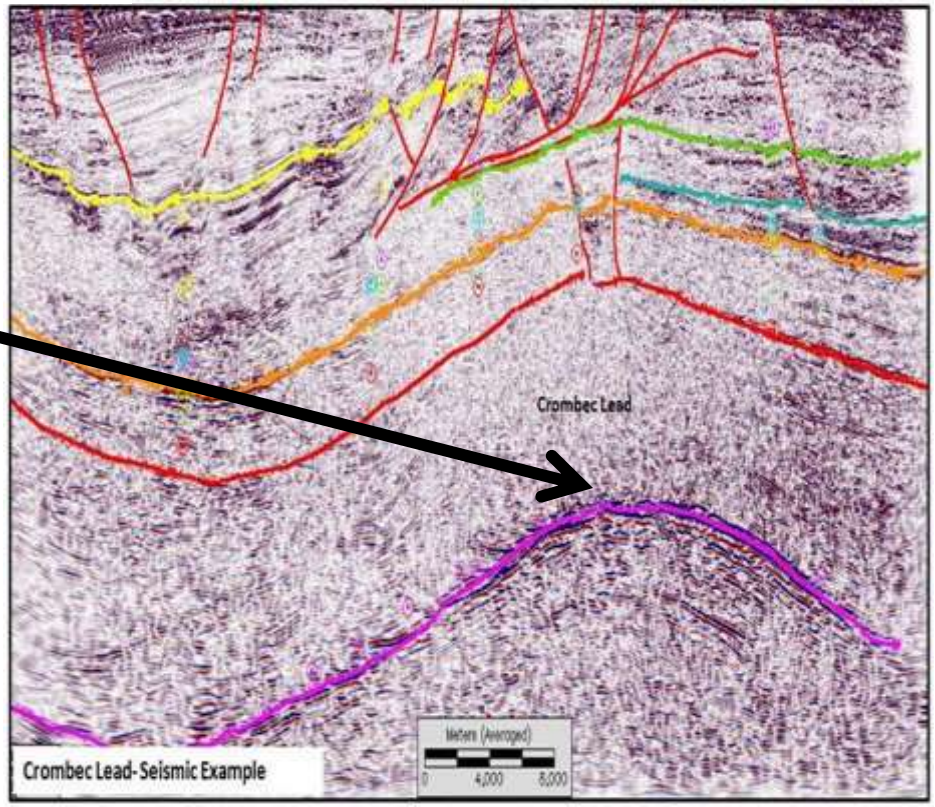
Types of Structural Traps

- Four Way Dip Closure



Map View

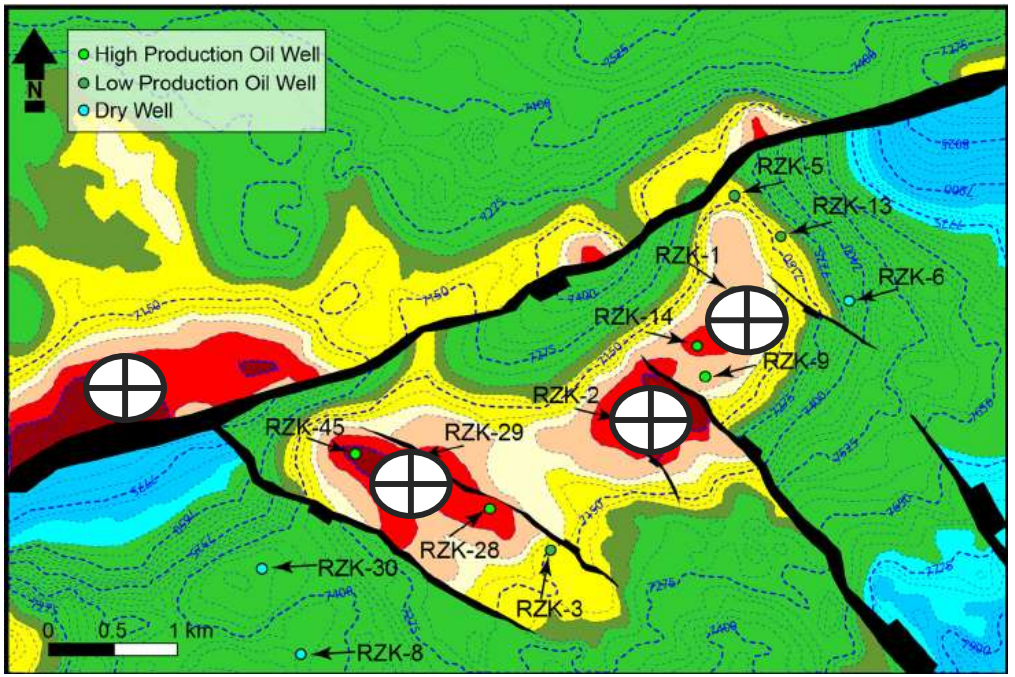
S N



Seismic View

Evaluating the structural traps

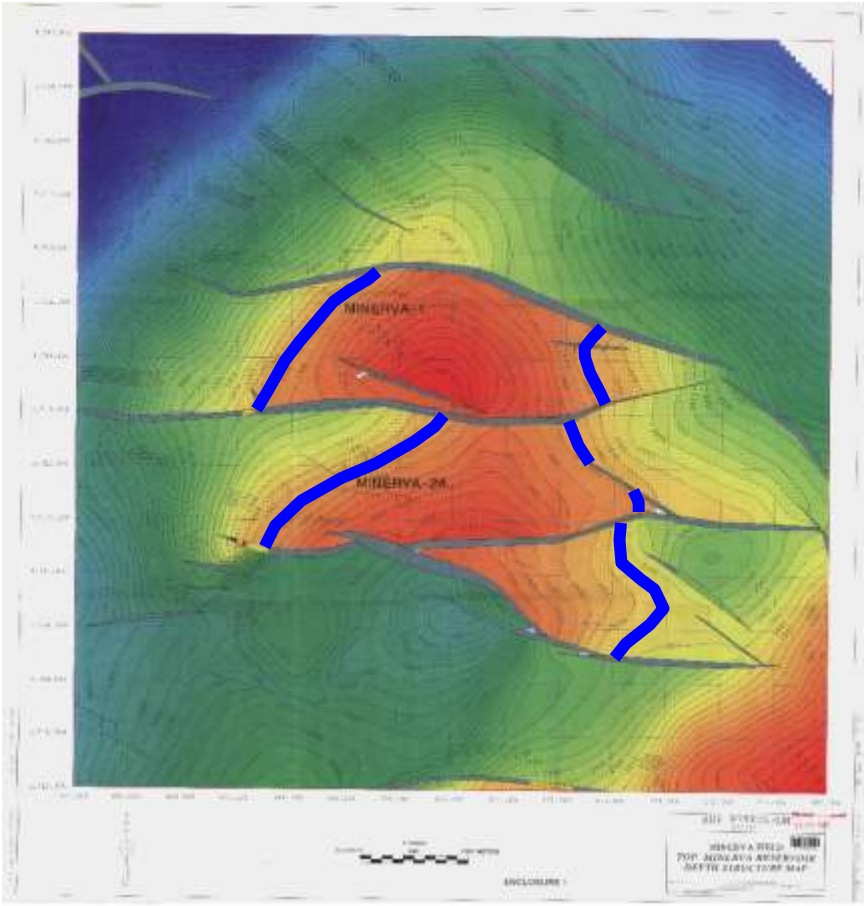
- After discussing the types of structural traps it is important to evaluate each one of them in order to decide which one of them is more promising.
- There is some factors should test each structural trap including the area , vertical closure and petrophysical parameters.



Evaluating the structural traps

Area

- The Area of the trap is calculated by defining the spill point of the trap which is the last closing contour or the hydrocarbon contact if it is known.



Evaluating the structural traps

Vertical Closure

- The Vertical Closure is defined as the difference between the top of the structure and the spill point.